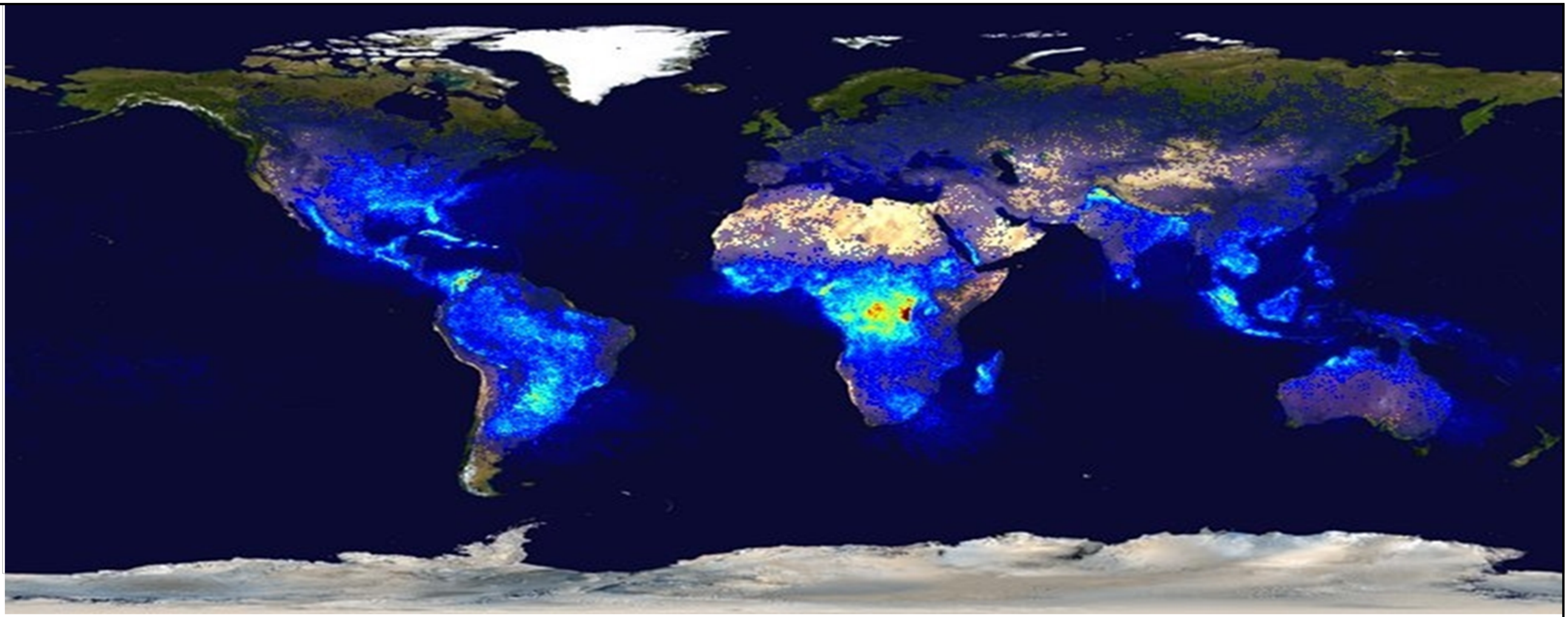

Low Voltage and Medium Voltage Surge Protection

Chris M. Finen, P.E. – Senior Application Engineer, Nashville TN

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Agenda

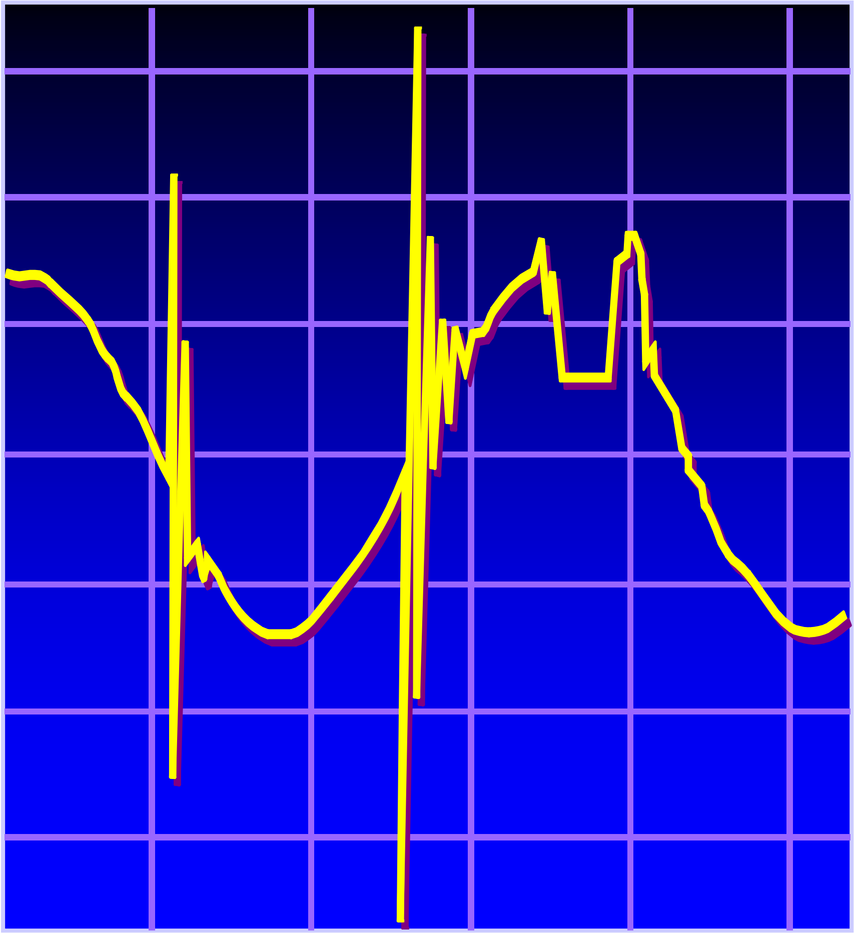
- Surge / Transient Basics
- Symptoms of Voltage Transients
- IEEE Standards / Test Waveforms
- Surge Protective Device (SPD) Design / Application
- NEC require surge protection
- Medium Voltage Lightning Arrestor Design / Application

What is a Voltage Transient?

Definition: a high rising voltage condition on one or more phases lasting 2 milliseconds or less

Characteristics:

- Duration - 50ns to 2ms
- Rise time - 10ns to 100µs
- Frequency - 20Hz to 20MHz (ringing transients)
- Voltage - up to 20kV



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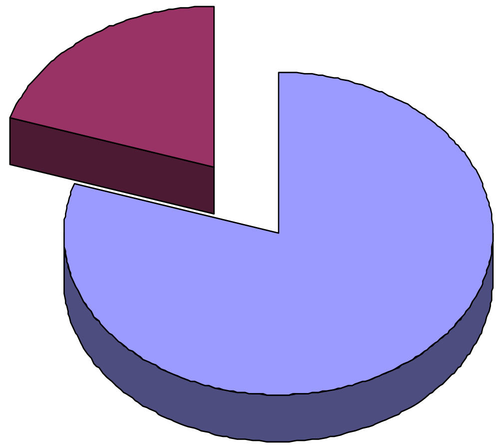
Where Do Voltage Transients Come From?



80% Internal

- Load switching
- Short circuits
- Capacitor switching
- Imaging equipment
- VS Drives
- Arc welders
- Light dimmers

20% External

- Lightning
- Grid switching
- Capacitor switching
- Short circuits

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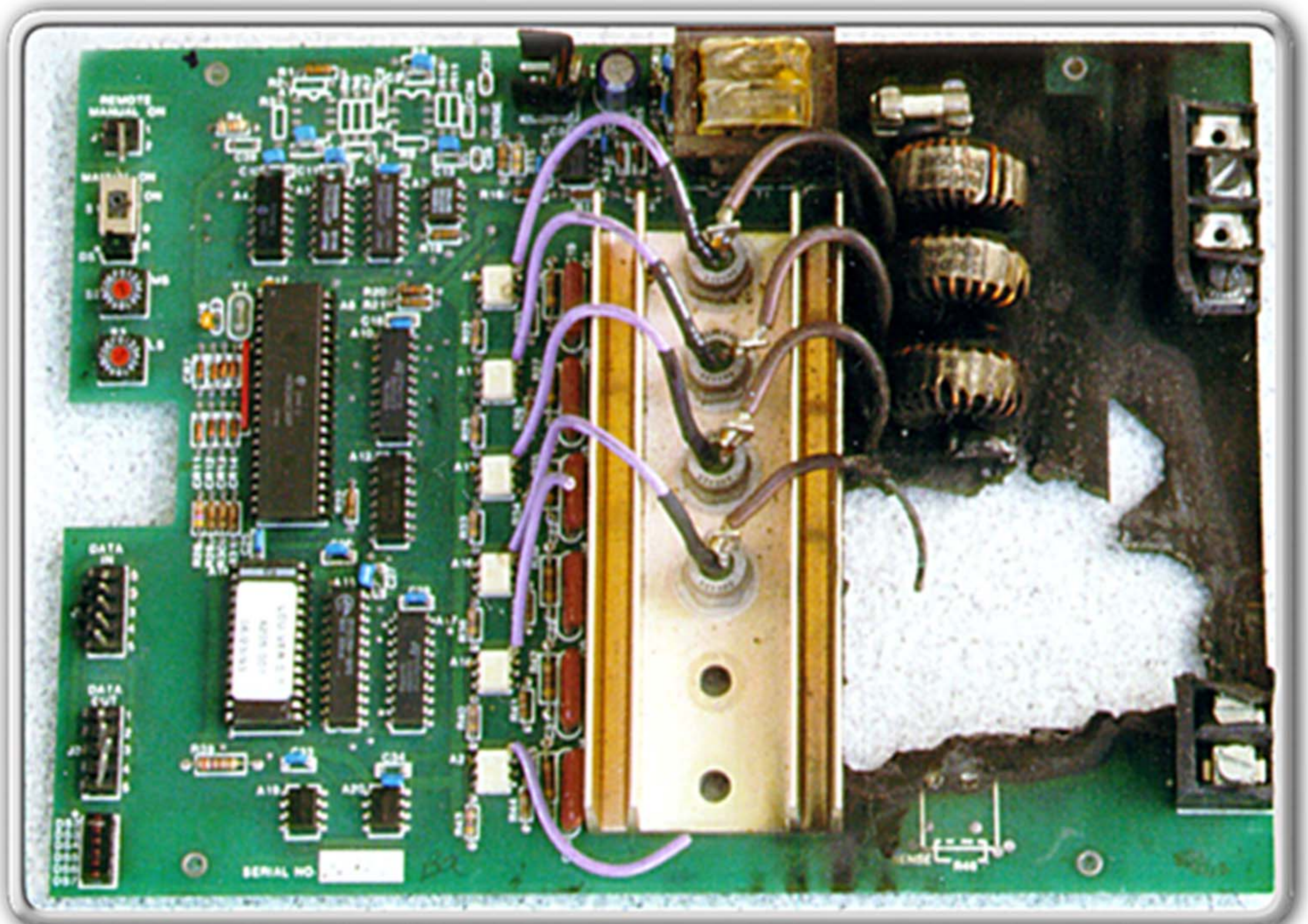
Symptoms of Voltage Transients

- Equipment damage
  - Power supplies & Input sections
- Equipment mis-operation
- Insulation breakdown of electrical conductors
- Premature aging of electrical and electronic equipment
- Process interruption
- Data loss and data transfer rate reduction

Equipment Damage from Transients



Catastrophic damage to equipment can occur as a result of a high energy transient voltage event

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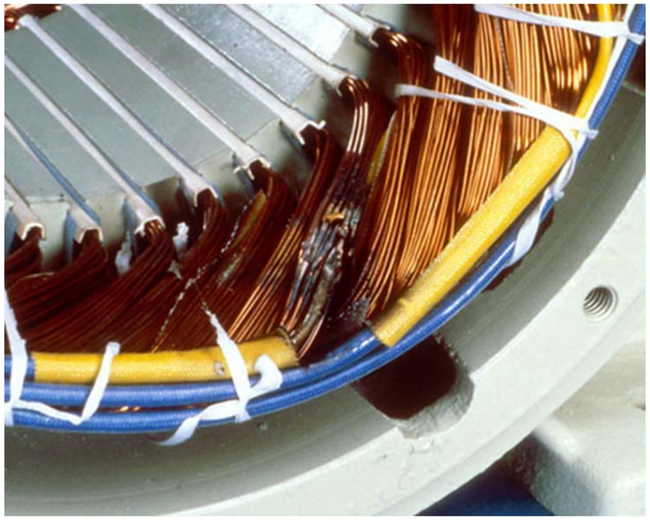
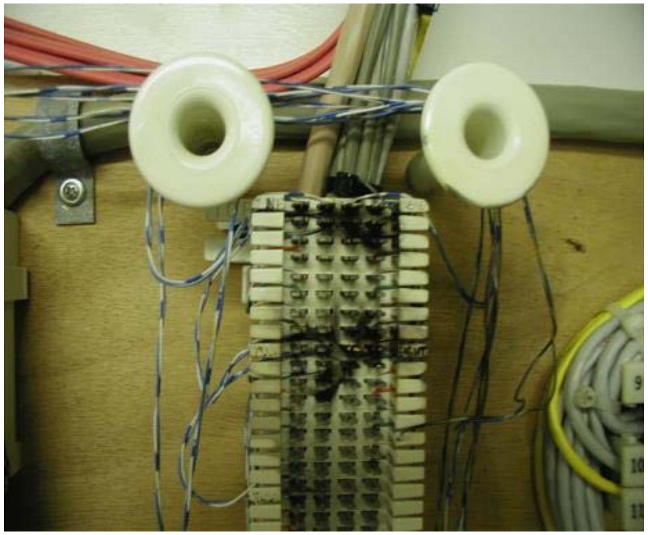
Insulation Breakdown on Conductors

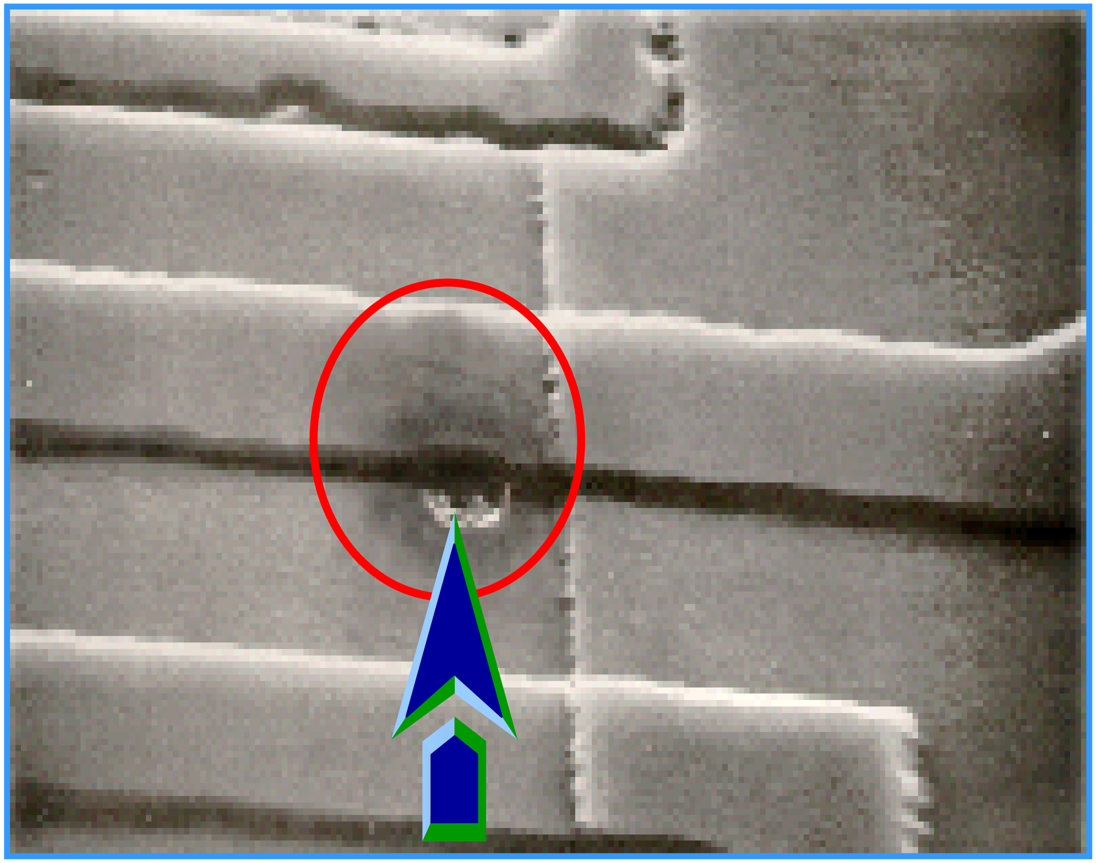
- Insulation rating on conductors is typically twice line voltage plus 1000V
- Transient voltages can be well in excess of 10kV – insulation breakdown and motor winding failure can occur
- Transient will affect any conductor including phone and data lines





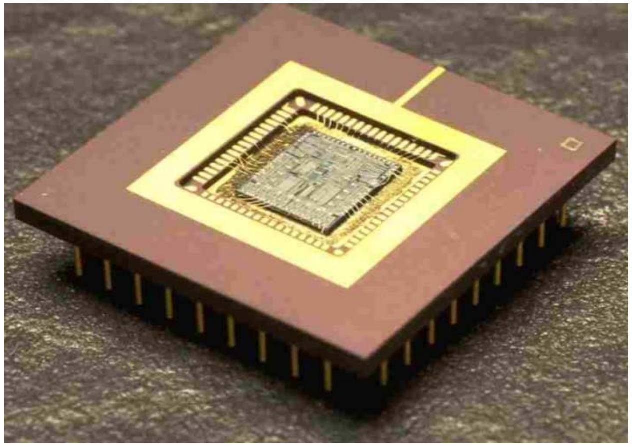
Premature Aging and Failure

- Damage to trace on electronic printed circuit board
- Likened to "Electronic Rust"



Data Disruption

Power disturbances create physical damage and affect logic signals in electronic equipment. Noise disturbances can be interpreted as legitimate ON/OFF signals, resulting in operating errors and equipment downtime.

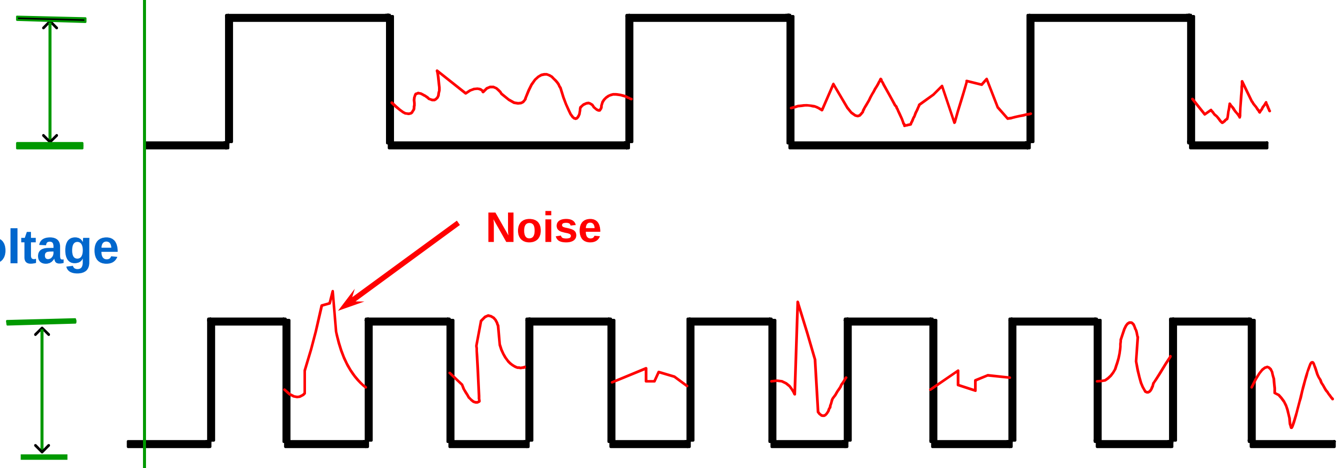


A. Signal Voltage Levels 1975

20 - 30V logic signal

B. Modern Voltage Levels

1.5 - 3V logic signal



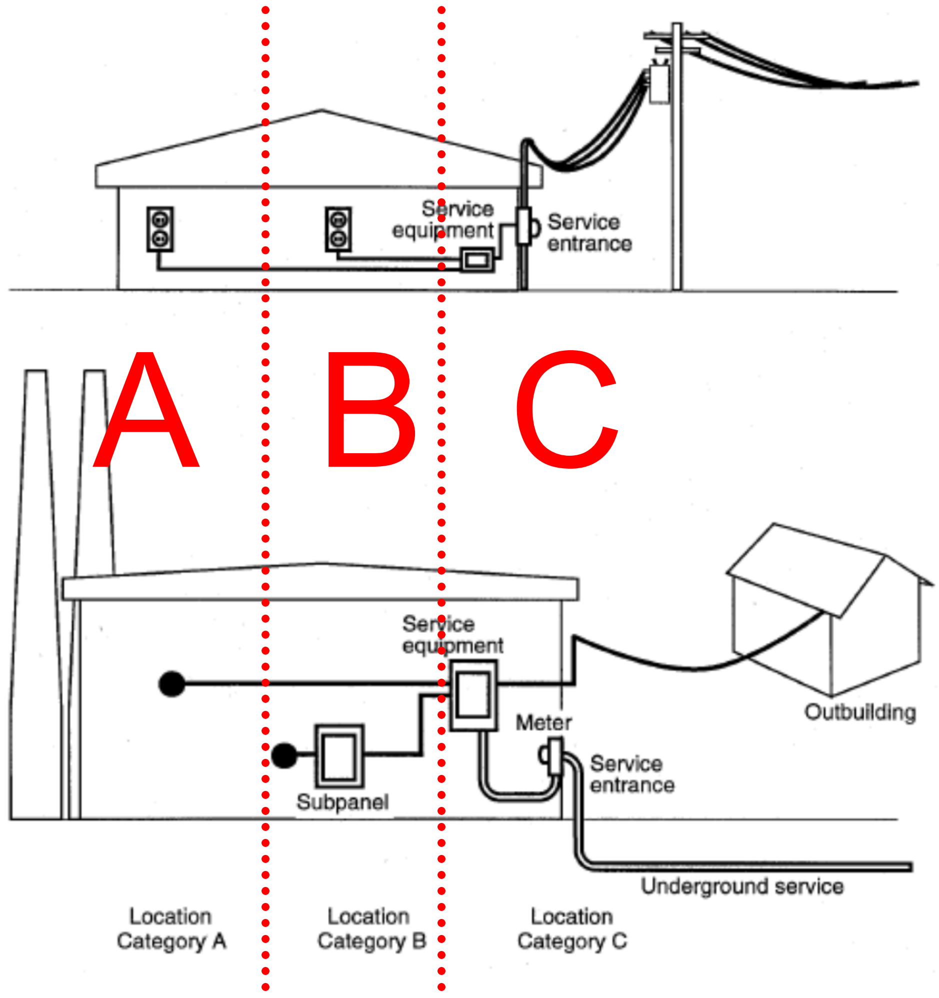
Source: EC&M

Arrester / Surge Protection Device Standards

- UL1449 – Standard for Surge Protective Devices (<1000v)
- IEEE Std C62.11 – Standard for Metal-Oxide Surge Arresters for AC Power Circuits
- IEEE Std C62.22 – Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems
- IEEE Std C62.41 – Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and less) AC Power Circuits
- IEEE Std C62.45 - Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits
- NFPA 780 – Standard for the Installation of Lightning Protection Systems
- UL 96A – Installation Requirements of Lightning Protection Systems

IEEE C62.41.1 Location Categories

- IEEE describes location categories
- IEEE also describes current and voltage levels that might be typical in these areas



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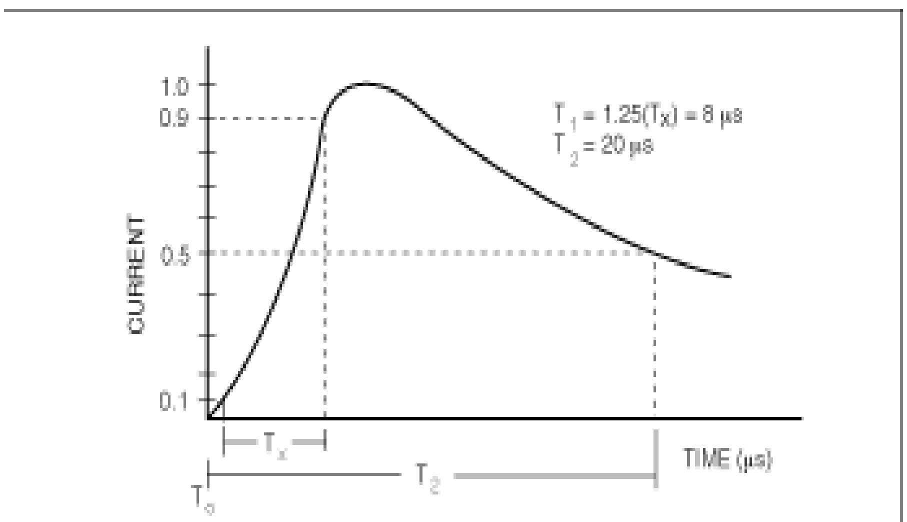
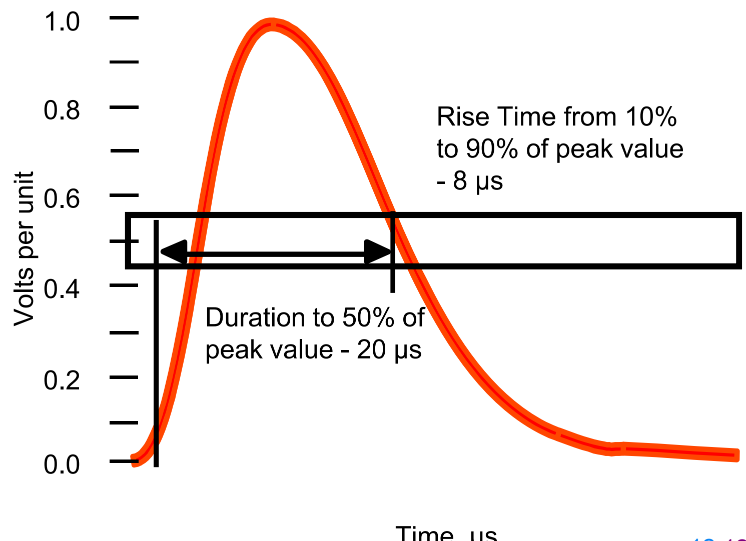
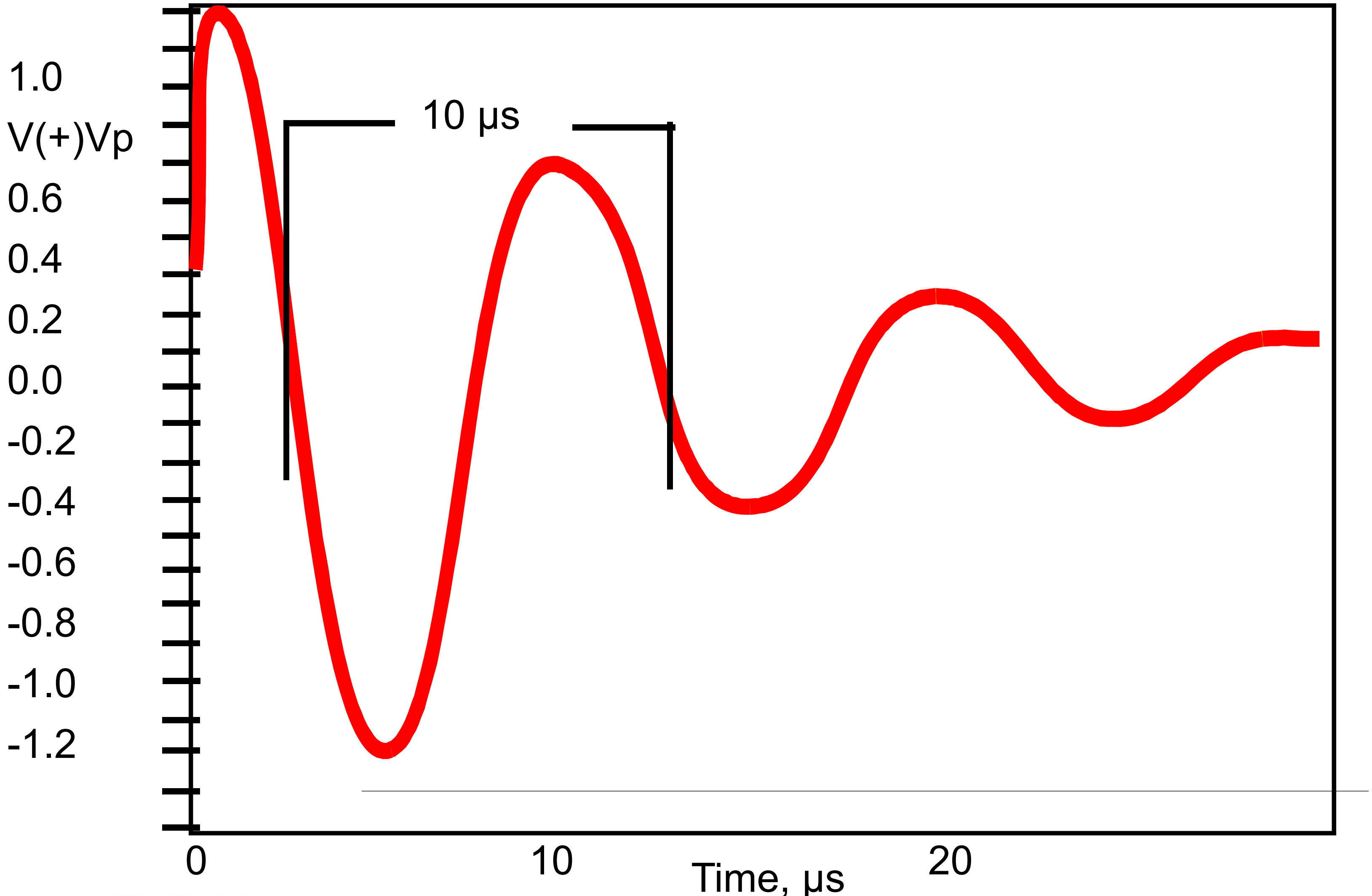
IEEE C62.41.1 8x20µs Combination Wave

- 8/20 (pronounced 8 by 20) combination wave is used by manufacturers to simulate lightning current to test surge protection designs
  - "8" is the peak rise time from 10%-90% in microseconds
  - "20" is the time to reach 50% of the peak value
  - Real world lightning usually has a 1 to 4 microsecond rise time





IEEE C62.41.1 100kHz Ring Wave



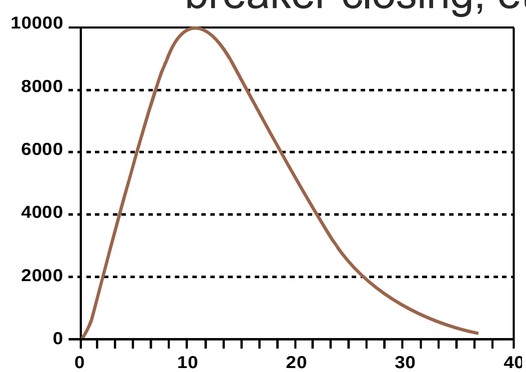
IEEE Test Waveforms used to represent surge activity

100kHz Ring Wave		
Location Category	Peak Values	
	Voltage	Current
A	6kV	200A
B	6kV	500A

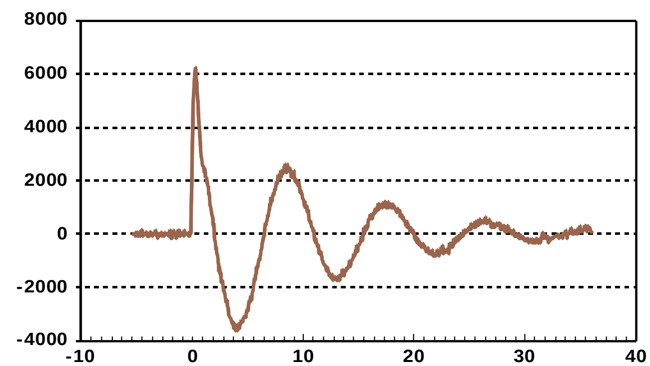
Combination Wave		
Location Category	Peak Values	
	Voltage	Current
A	6kV	500A
B	6kV	3000A

Combination Wave		
Location Category	Peak Values	
	Voltage	Current
C low	6kV	3kA
C high	20kV	10kA

- Category C3 (20kV, 10kA)
  - Represents the high level surge imposed on an electrical system service entrance due to a direct lightning striking
- Category C1 (6kV, 3kA)
  - Represents a lower order surge on a service entrance caused by switching events, distance lightning strikes, etc.
- Category B3 (6kV, 500A 100kHz Ringwave)
  - Represents a typical internally generated repetitive surge event due to motor starting, capacitor switching, breaker closing, etc.



Combination Wave



Ring Wave

Surge Suppressors Act As "Pressure Relief Valves"

- The ideal surge suppressor shunts harmful surge current to **ground** under a surge condition and appears as a high impedance under normal operating conditions
- The surge suppressor is a self sacrificing device – bearing the brunt of harmful surge currents

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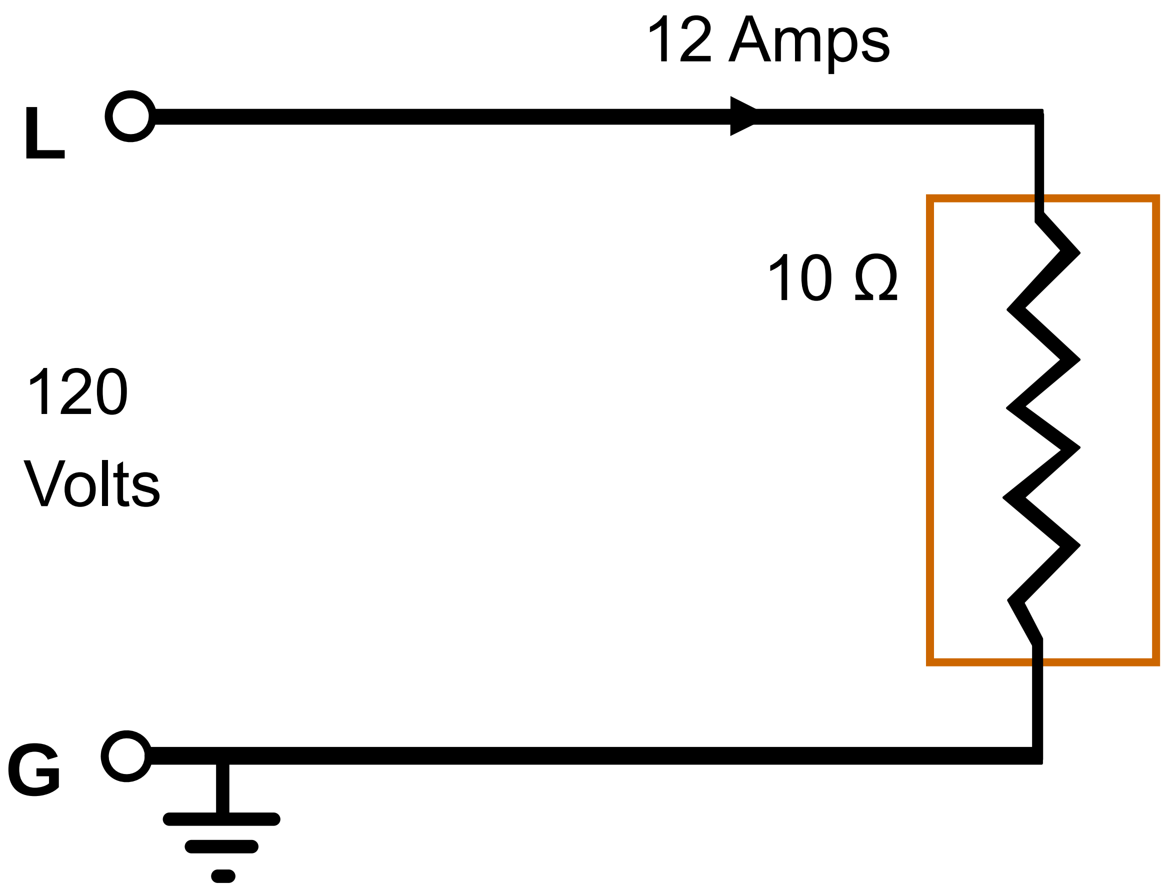
Normal Operation - No Protection



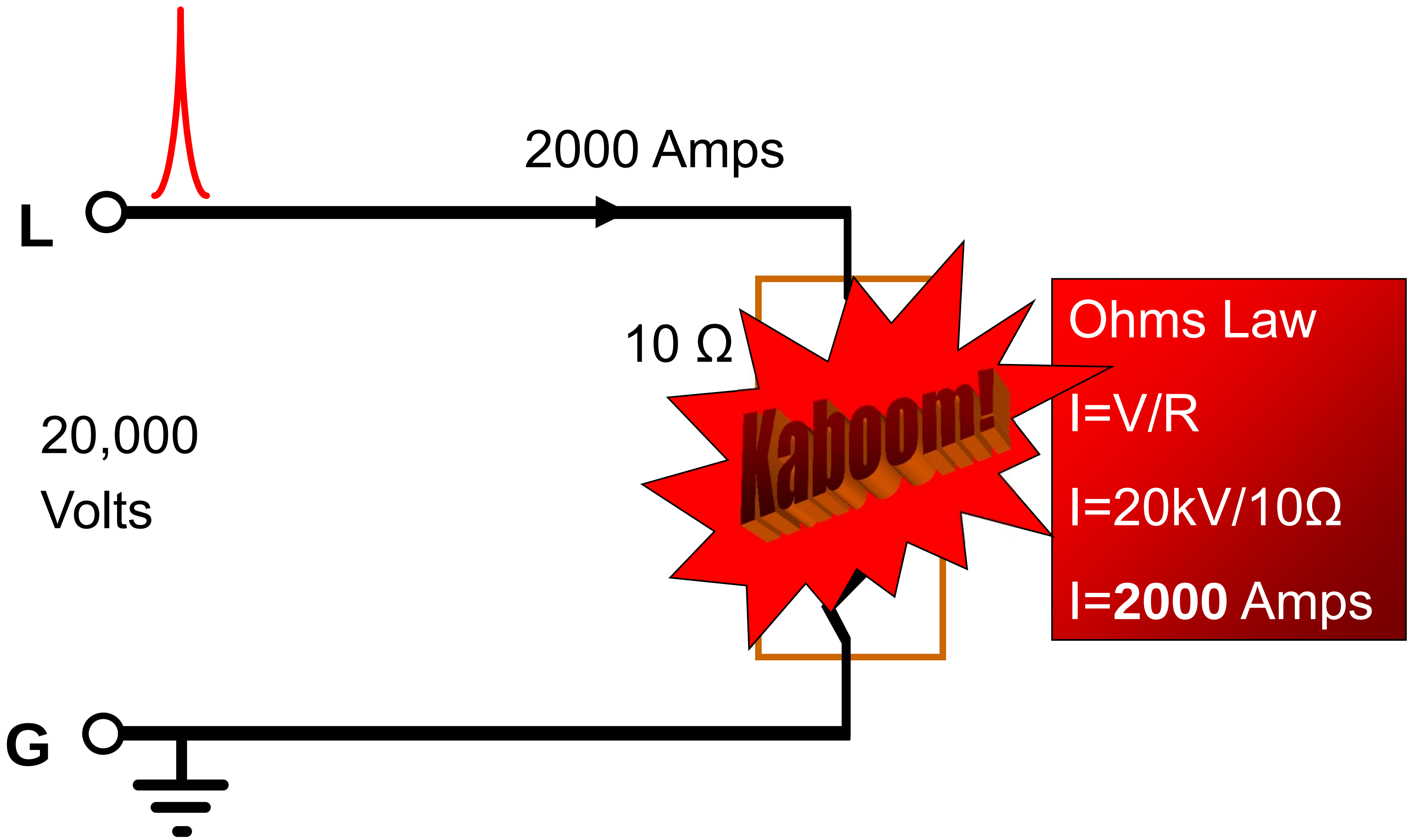
Ohms Law

I=V/R

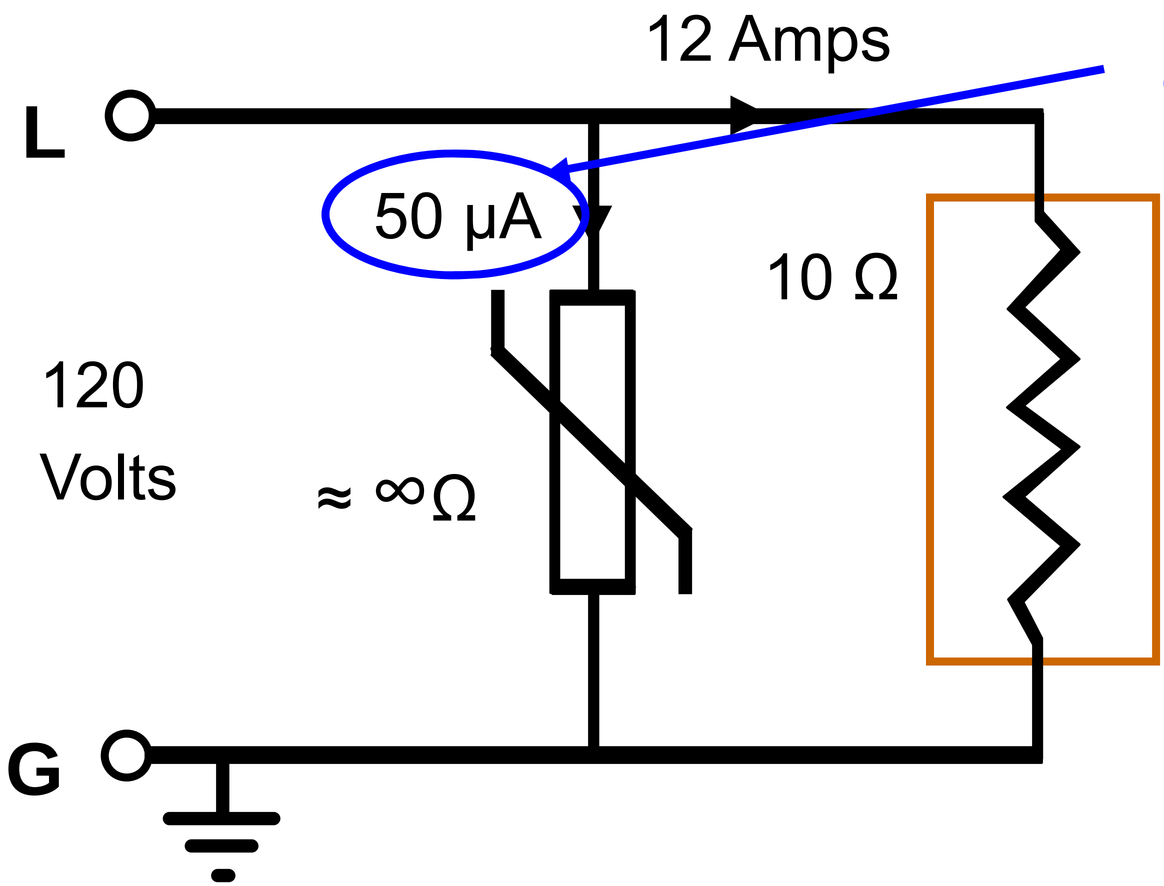
I=120V/10Ω

I=**12** Amps

Surge - No Protection



Normal Operation - Protection



Leakage current has very negligible effect on circuit

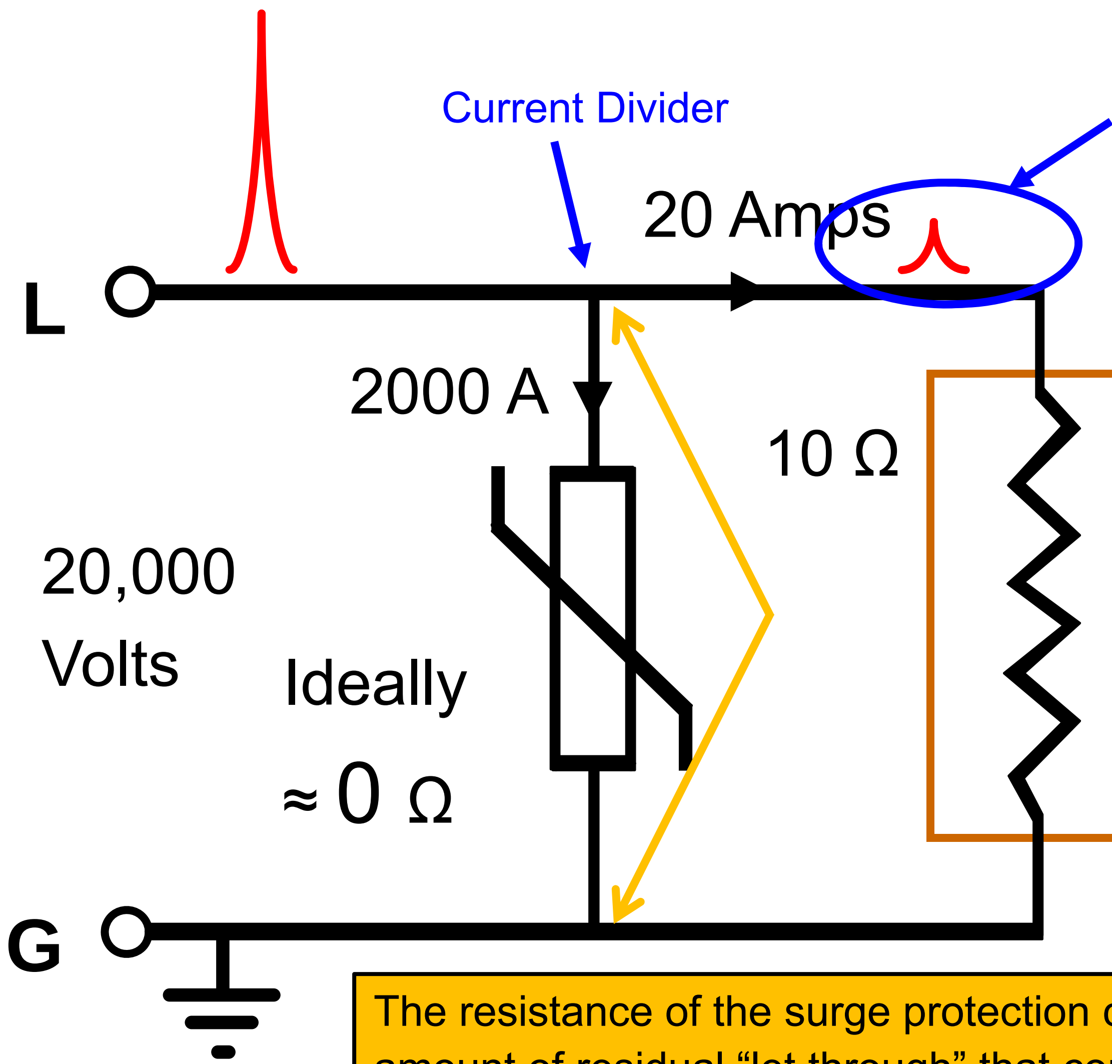
Ohms Law

I=V/R

I=120V/10Ω

I=**12** Amps

Surge - With Protection



Some residual "let-through" voltage. Hopefully manageable by load

Ohms Law

V=IR

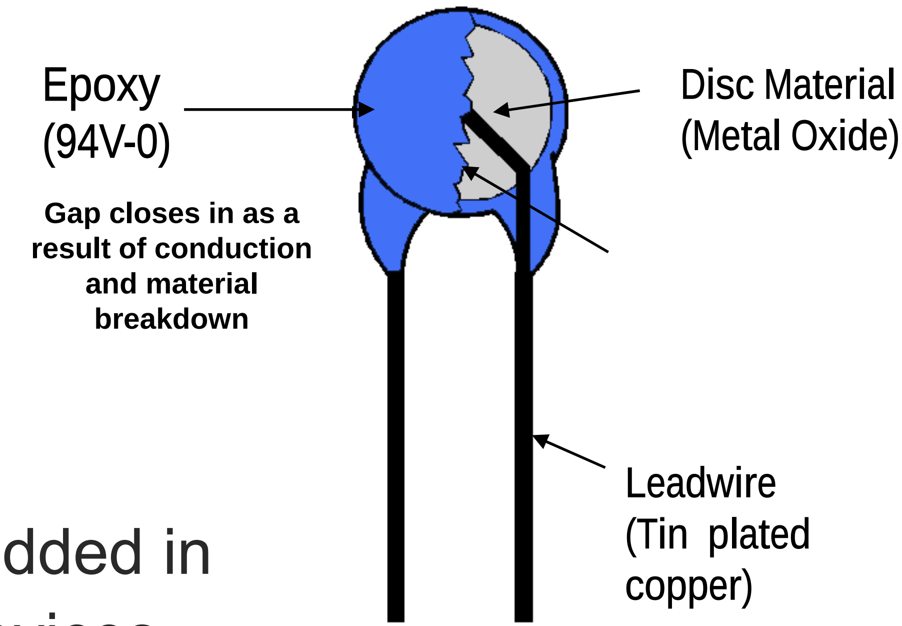
V=20A*10Ω

V=**200 Volts**

The resistance of the surge protection circuit to ground drives the amount of residual "let through" that continues to load. Needs to be as low as possible!

Metal Oxide Varistors – Most Common Technology Used in SPD

- The vast majority of surge suppressors today use Metal Oxide Varistors (MOV's) as the common building block for surge diversion
- MOV's are:
  - Rugged
  - Long life
  - Fast reaction time
  - Relatively inexpensive
- Same devices that are imbedded in many sensitive electronic devices (VFD's, Power Supplies, etc.)

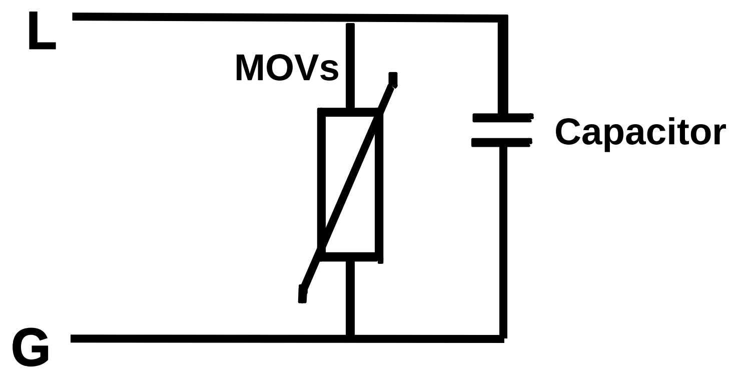


Filtering in Surge Protective Devices

Lower Let-Through Voltage: Capacitive filters provide an additional low impedance shunt path for both impulse and ringwaves.

Noise Attenuation: Removes low voltage high frequency disturbances at any phase angle ("sinewave tracking").

Reliability: Better performance, longer life and noise attenuation provide more "value" than a "MOV only" device.

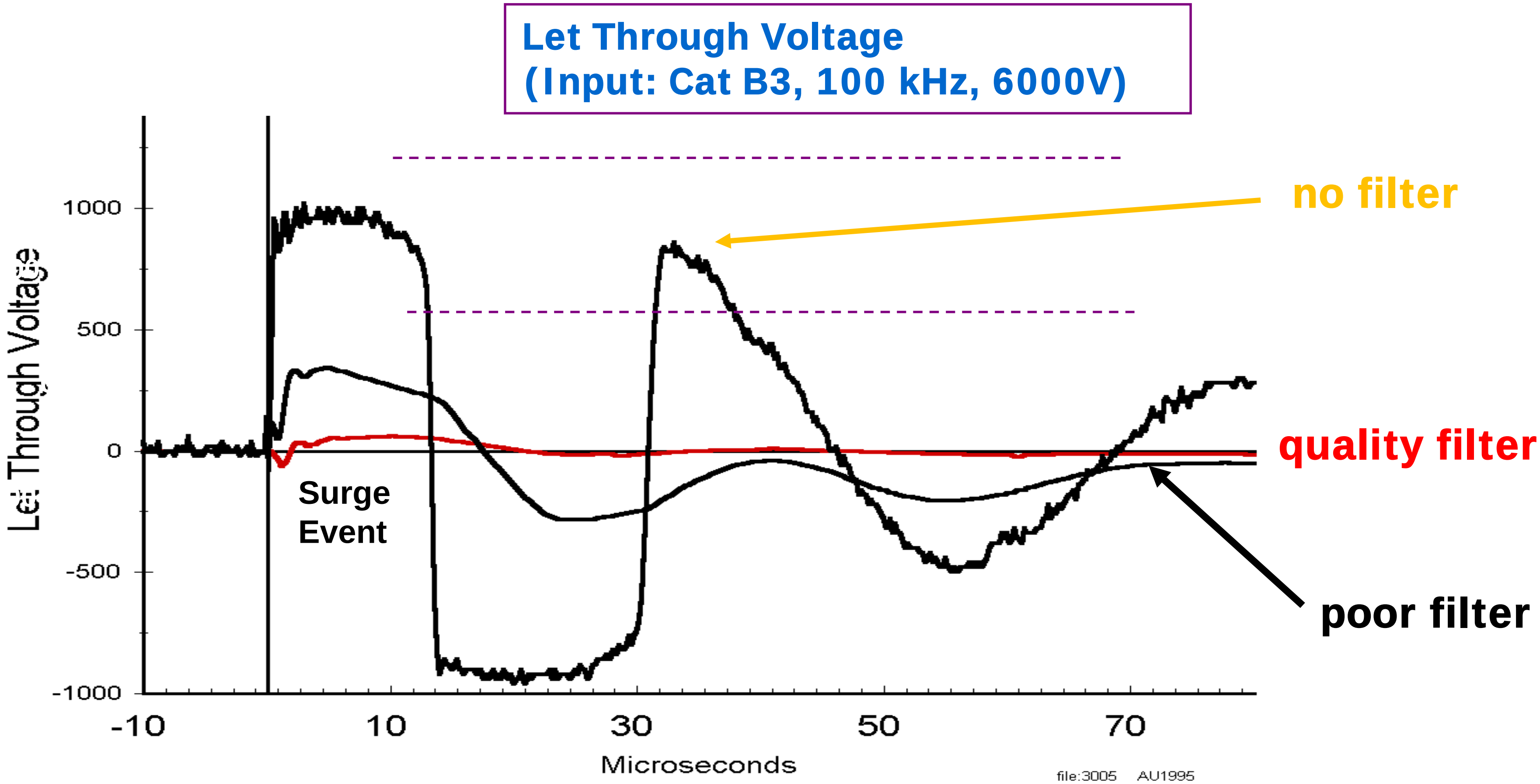


$$Z_{cap} = \frac{1}{2\pi f}$$

"Hybrid SPD" "Sinewave Tracking"

"Responsive Circuitry"

Hybrid Filter Design Offers The Best Protection



SPD filtering components are usually specified in dB of noise attenuation. Good quality filters produce at least 45 – 50dB of attenuation.

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Applicable Current / Voltage Ratings for SPDs

- Peak surge current rating
  - Measure of life or longevity expectations of SPD
  - Also referred to as "single impulse rating", "maximum current rating" or "life rating"
- Nominal discharge current rating
  - Measure of ruggedness or durability of SPD in the electrical system
- Voltage System Configuration
  - Nominal System Voltage
  - Wye or Delta

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Peak surge current rating (kA/Phase or kA/Mode)

- The peak surge current is a predictor of how long an SPD will last in a given environment
  - The higher the kA, the longer the life of the MOVs
- Similar to the tread on a tire
  - The thicker the tread, the longer the tire will last
- Peak surge current = Life

An SPD will never be subjected to its peak surge current rating in actual installed conditions!

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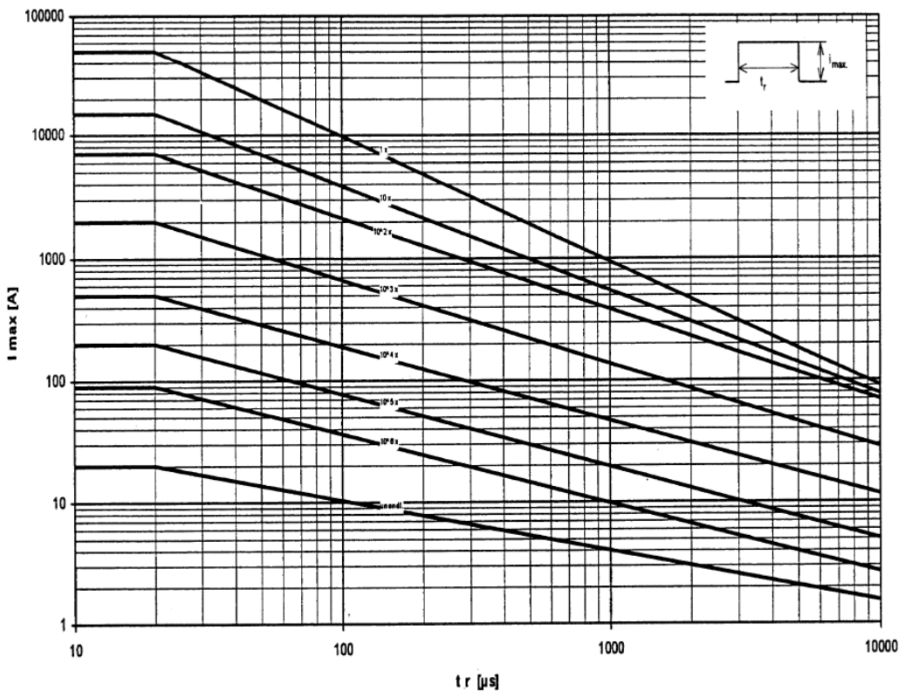
Life curve for 50kA MOV



current level (amps)	# of strikes (useful life)
50,000	1
13,000	10
7,000	100
2,000	1,000
500	10,000
200	100,000
90	1,000,000
20	unlimited

- All MOV’s degrade slightly over time depending on the magnitude and duration of the impulses it is subjected to (8x20 µs is most common test waveform)

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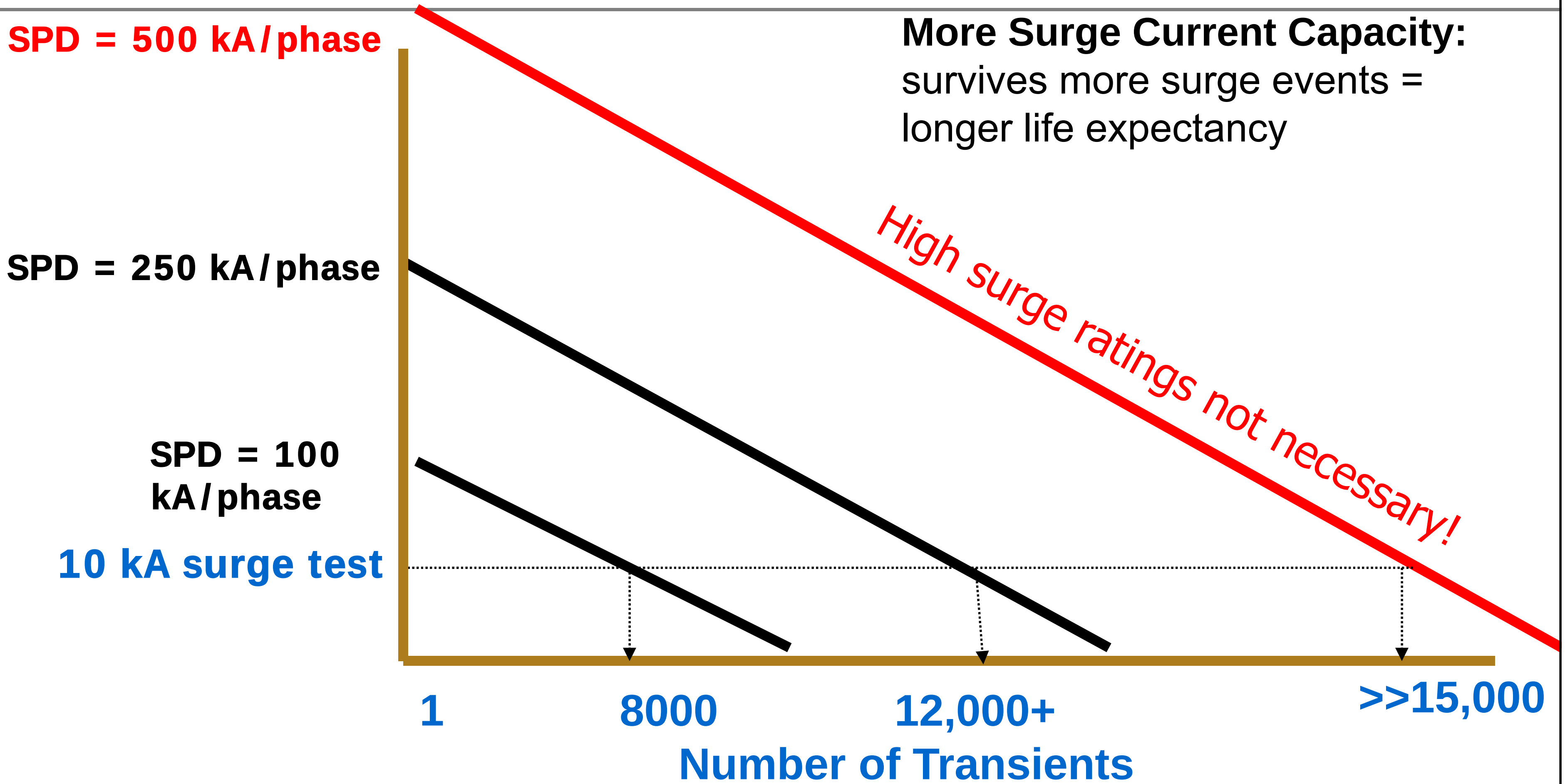
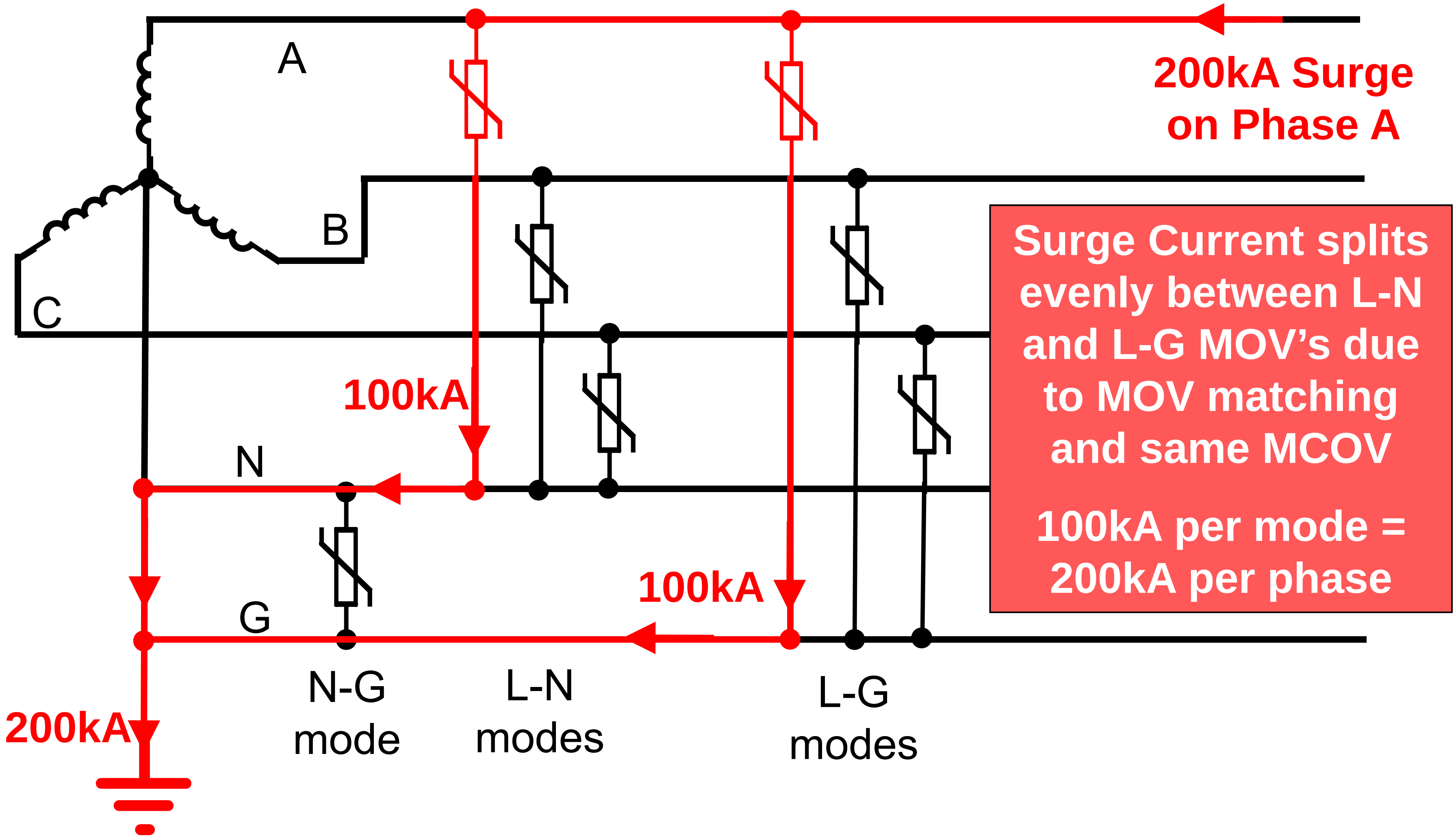
Surge Current Ratings: Higher Capacity = Increased SPD Life



- 250 kA/phase is enough for any facility (>> 25 year life in Florida)
- Significant $$$ for higher kA rated units with life expectancy > **200 years**
- Capital is better spent elsewhere

Per Mode / Per Phase
3 Phase – 4 Wire System



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Maximum Continuous Operating Voltage

- The maximum rms voltage that can be applied to each mode of the SPD
- This is a manufacturer selected value
- Users and specifiers should make sure there is enough “head-room” so that normal voltage fluctuations do not exceed the MCOV

Typical MCOVs

120V system – 150V MCOV

240V system – 320V MCOV

480V system – 550V MCOV

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Nominal Discharge Current - I_n

- Stress test
- Nominal discharge current tests the complete SPD under strenuous "real life" scenarios
  - MOV's, circuit protection, leads, resistors, circuit boards, etc.
- Similar to a test track or road test for an auto

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Nominal Discharge Current (I_n) Test

- Manufacturer chooses a current they want to test with:
  - Type 1 – 10kA or 20kA
  - Type 2 – 3kA, 5kA, 10kA or 20kA
- Complete SPD is tested along with any required overcurrent devices (fuse or breaker)
- Measured let through voltage for a 6000V, 3000A surge is recorded
- SPD is subjected to 15 surges at chosen nominal discharge current (I_n), one minute apart with rated voltage applied between surges
- Measured let through voltage for a 6000V, 3000A surge is recorded again – <u>let through voltage must not deviate more than 10% from original voltage</u>

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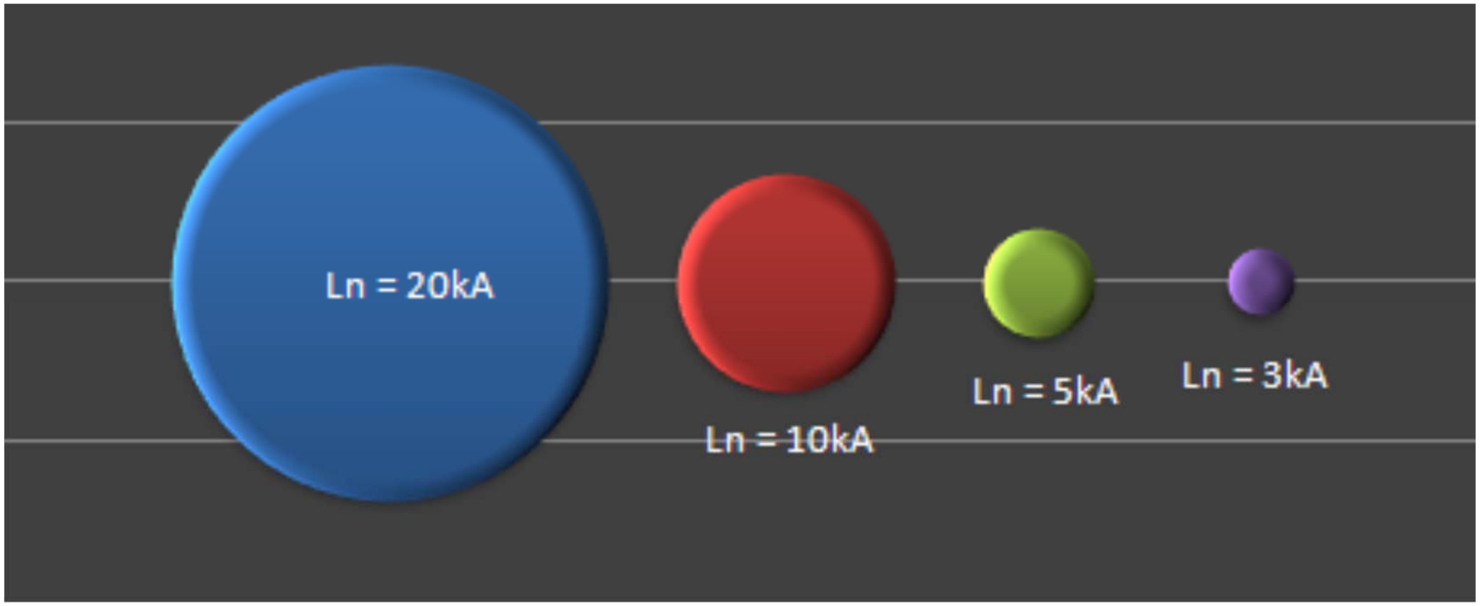
Nominal Discharge Current (I_n)



Energy = I^2*R

- 10kA SPD is only subjected to 25% of the energy of 20kA
- 5kA SPD is only subjected to 6.25% of the energy of 20kA
- 3kA SPD is only subjected to 2.25% of the energy of 20kA

The higher the nominal discharge current rating, the more rugged and robust the SPD.

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Voltage System Configuration

- It is extremely important that the configuration of the SPD is compatible with the system voltage configuration
- Delta SPD's <u>can</u> be connected on a Wye system
  - Not recommended because it provides less protection
  - Voltage Protection Rating (Let Through Voltage) would be higher
  - MOV's are connected L – L and L – G but have MCOV above the nominal L – L voltage
    - Example: 480v Delta = 550v MCOV
- Wye SPD's can <u>NOT</u> by connected on a Delta system
  - L – G connected MOV's have an MCOV rating based on L – N voltage
    - During a Ground Fault, full line voltage is put across the L-G connected MOV's

#1 Contributing Factor in Effective Surge Protection = Installation

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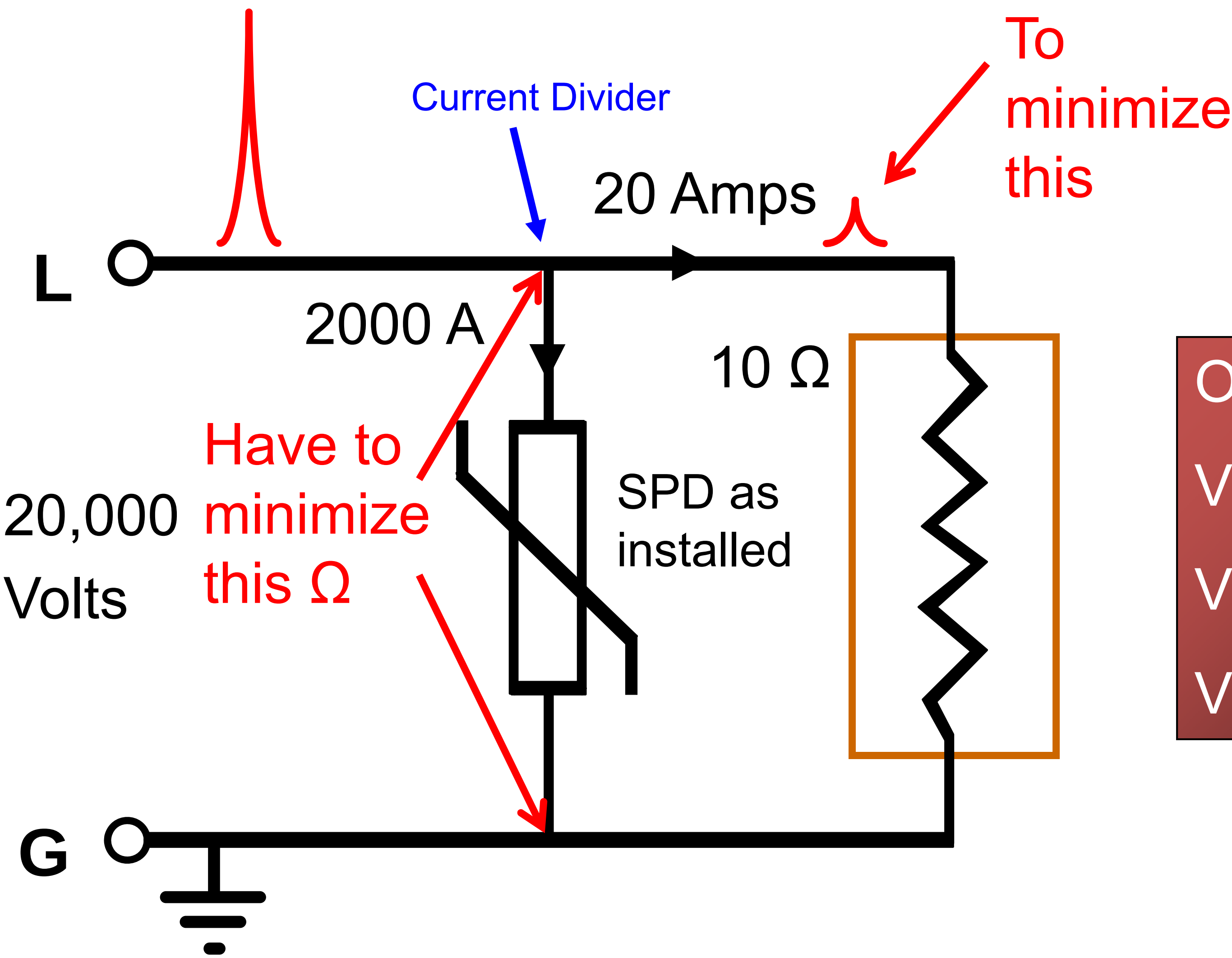
Voltage Protection Rating

- VPR is a rating published and marked on all UL 1449 listed SPDs
- Residual voltage from a 6kV, 3000A 8/20 µs surge waveform impulse (Worst of 3 consecutive tests)
- Tested with **<u>6 inches of cable leads</u>** protruding from the unit
- This is the real "performance" indicator for a surge protective device
- THIS IS WHAT YOU ARE PAYING FOR!!!

Measured Limiting Voltage	Voltage Protection Rating
330 or less	330
331 - 400	400
401 - 500	500
501 - 600	600
601 - 700	700
701 - 800	800
801 - 900	900
901 - 1000	1000
1001 -1200	1200
1201 - 1500	1500
1501 - 1800	1800
1801 - 2000	2000
2001 - 2500	2500
2501 - 3000	3000
3001 - 4000	4000
4001 - 5000	5000
5001 - 6000	6000

Remember our current divider…



Ohms Law

V=IR

V=20A*10Ω

V=**200 Volts**

Surge Installation Demonstration Video

- To get published performance, SPD must be installed with 6” of cable or less
- Additional cable length increases let through voltage by 15 – 25v per inch of cable.
- Demonstration Video
  - View full video:
    - http://videos.eaton.com/
  - Power Experience Center - Dan Carnovale
    - 1:38 – 2:46

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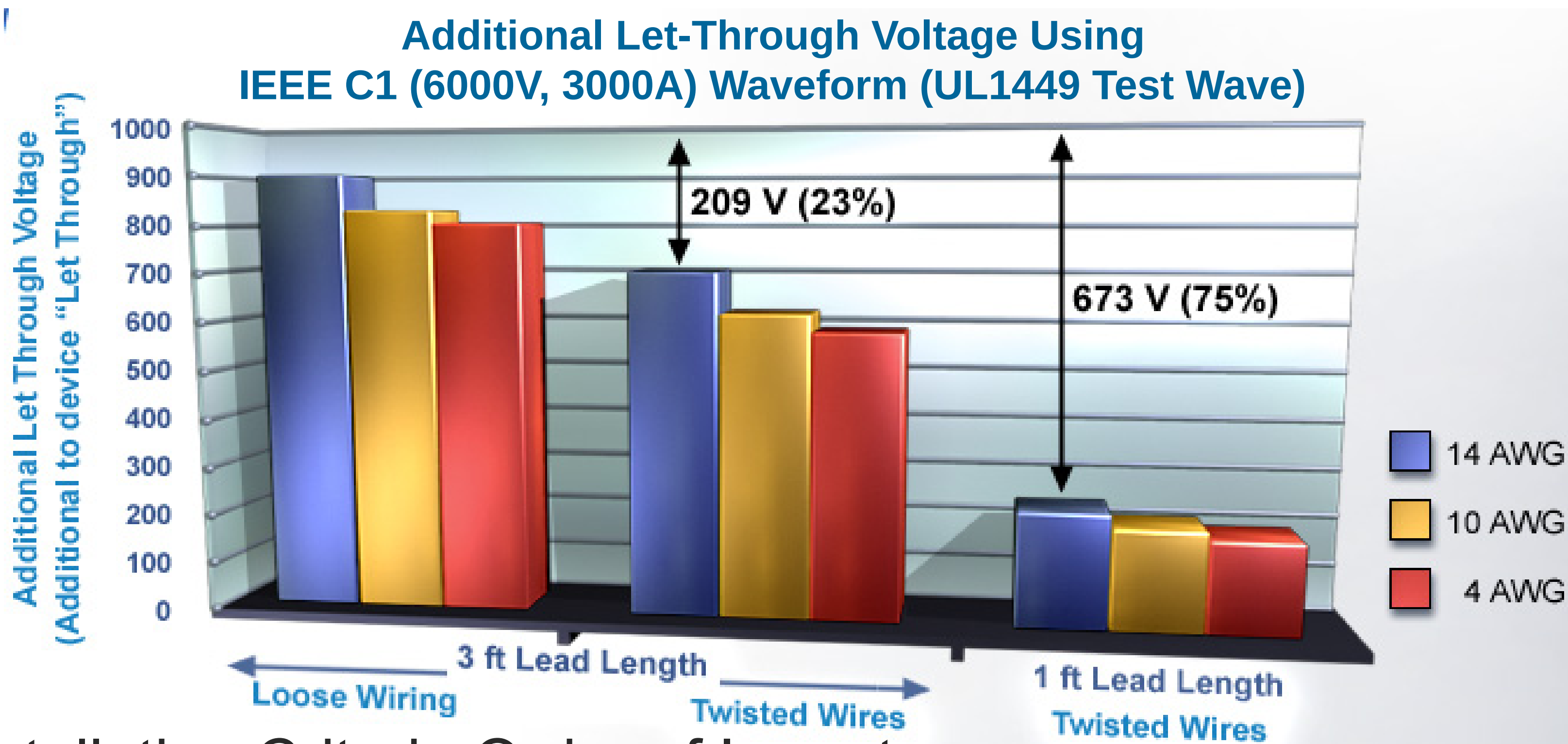
Installation Lead Length Can Increase Let-Through Voltage by 15- 25v Per Inch



Installation Criteria Order of Importance:

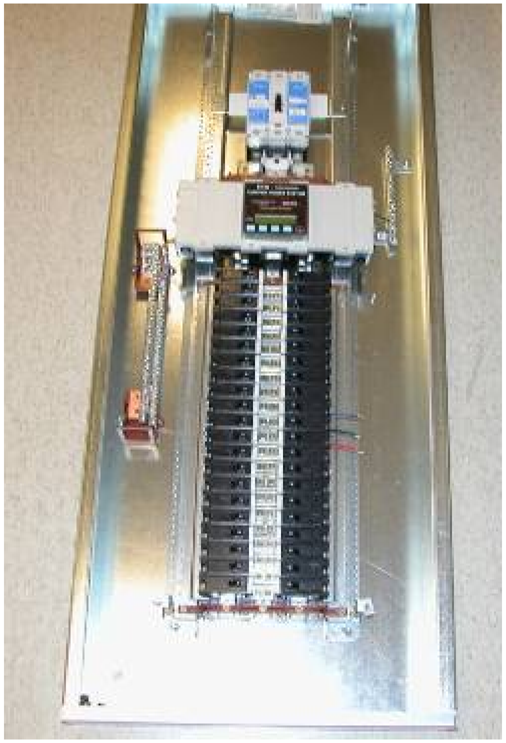
1) Lead Length - 75% reduction
2) Twisting Wires - 23% reduction
3) Larger Wire - minimal reduction

Connection of SPD's

Good | Better | Best

Sidemounted
(~14" of twisted conductor)

Integrated with Disconnect
(~6" of twisted conductor)



Direct bus connected
(No conductor length)

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Incorrect Installation Example

- Customer asked us, "Why am I having surge damage even though I have an SPD?"

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Calculation of $VPR_{Installed}$

- $VPR_{Installed}$ = VPR_{SPD} + Voltage Drop of Leads
- VPR_{SPD} = 700V
- Voltage drop of leads = 20ft x 180V per foot (#10 AWG untwisted wire) = 3,600V
- $VPR_{Installed}$ = 4,300V

Very high let-through voltage – SPD is not effective due to installation method!!

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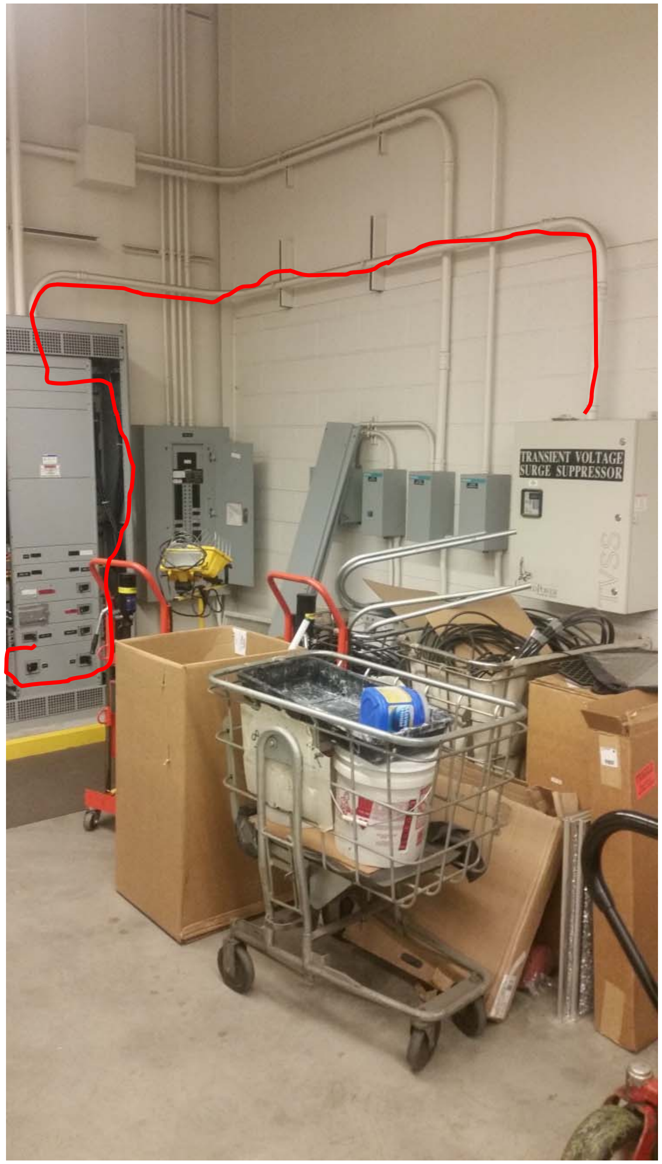
Another Incorrect Installation

- $VPR_{Installed} = VPR_{SPD} +$ Voltage Drop of Leads
- $VPR_{SPD} = 700V$
- Voltage drop of leads = 35ft x 120V per foot (#10 AWG untwisted wire) = 4,200V
- $VPR_{Installed} = 4{,}900V$



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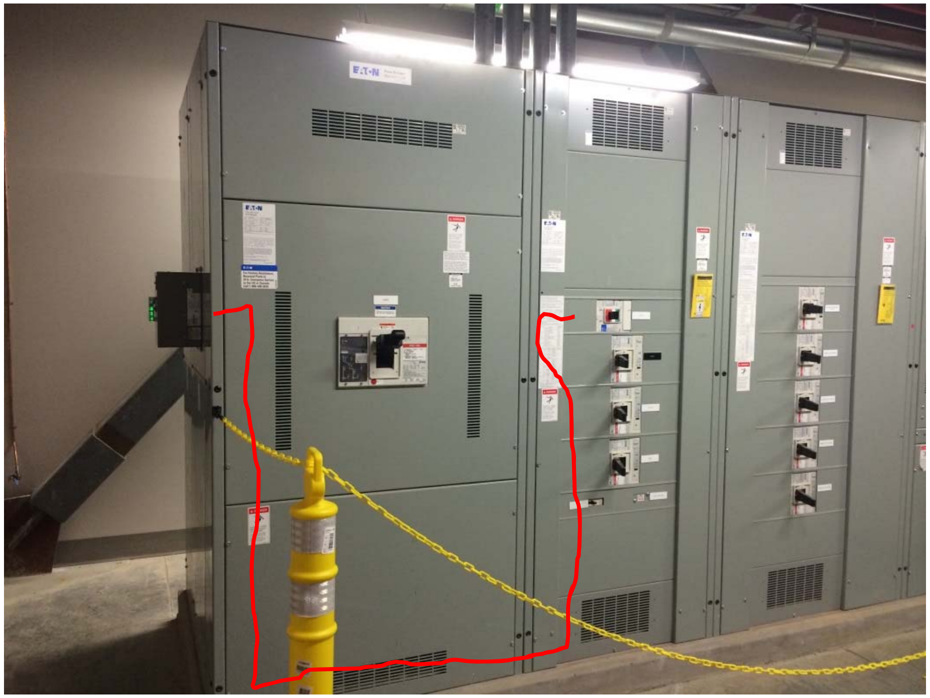
Looks good, but is it?



- $VPR_{Installed}$ = VPR_{SPD} + Voltage Drop of Leads
- VPR_{SPD} = 700V
- Voltage drop of leads = 15ft x 120V/foot (10 AWG untwisted) = 1,800V
- $VPR_{Installed}$ = 2,500V

Would have been 700V if Integrated!

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2014 NEC – Article 700.8 Emergency System Panels

Typical applications

NEC Article 700.8 requires surge protection to ensure reliability of critical emergency systems such as:

- Medical facility Life Safety Branch Panels
- Emergency lighting panels
- Emergency communication systems
- Fire control systems
- Elevators used for evacuation
- All other emergency panels, circuits and equipment

Surge protection

NEC surge protection requirement for emergency power systems

New requirement within 2014 National Electrical Code® (NEC®): Code change NEC 700.8—Surge protection required for emergency power panels

The 2014 National Electrical Code, Article 700.8, states: "A listed SPD shall be installed in or on all emergency systems switchboards and panelboards." The change requires surge protection to be installed on all emergency electrical equipment to improve the reliability of emergency power systems. The NEC defines emergency power systems as systems legally required to automatically supply power to designated loads upon loss of normal power. Protection of emergency systems is achieved by installing surge protection on panelboards, switchboards and other critical equipment.

Typical applications

Article 700.8 requires surge protection to ensure reliability of critical emergency systems such as:

- Medical care facilities
- Emergency lighting panels
- Emergency communication systems
- Fire control systems
- Elevators used for evacuation
- All other emergency panels, circuits and equipment

Recommended solutions

For new construction applications, integrating surge products into panelboards and switchboards provides the most reliable solution with superior performance.

Eaton's SPD series of surge protection products provides maximum surge protection with superior reliability. For existing installations, Eaton makes a complete line of products to meet your risk exposure needs.

Healthcare

Industrial

Data centers

Commercial

To contact an Eaton salesperson or local distributor, please visit
Eaton.com/spd

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2017 NEC has 4 new code requirements

- Beginning 2008 the NEC began requiring surge protection. The first article added was to 708.20 regarding Critical Operation Power Systems (COPS).
- In 2011 the NEC began requiring surge protection for wind generation by adding to Article 694.7 (d).
- In 2014 NEC added to Article 700.8 requiring surge protection for emergency circuits.
- The 2017 NEC adds 4 more requirements for surge protection

2017 NEC – 620.51(E)

Elevators, moving sidewalks, escalators, and more…

- Article 620.51(E) was added to address emergency system loads, such as elevators, escalators, moving walkways, and chairlifts. These are systems that are a matter of public safety. It states, "Where any of the disconnecting means in 620.51 has been designated as supplying an emergency system load, surge protection shall be provided".

2017 NEC – 645.18

Critical Data Systems

- Article 645.18 - Surge protection is required for critical operations data systems. The NEC defines these as "information technology equipment systems that require continuous operation for reasons of public safety, emergency management, national security, or business continuity."
- Failures to this equipment may not only cause undue financial harm to businesses but may also pose a public safety risk. As such, it is imperative to ensure the integrity of these systems, and surge protection is an important part of that safeguard.

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2017 NEC – 670.6

Industrial Machinery

- Article 670.6 addresses industrial equipment with safety interlock circuits. It states that "industrial machinery with safety interlock circuits shall have surge protection installed."
- The concern is that electrical surges may cause the interlocks to fail independent of the machine operation. This could pose a significant safety risk for operators, as the intended safety mechanisms may be disabled unbeknownst to the operator.

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2017 NEC – 695.15

Fire Pumps

- 695.15 – "A listed surge protection device shall be installed in or on the fire pump."
- A study conducted by the NFPA Fire Protection Research Foundation concluded that 12% of fire pumps tested had damage due to surge activity. Surge can damage motor windings and pump controls leaving critical equipment vulnerable during an critical emergency.

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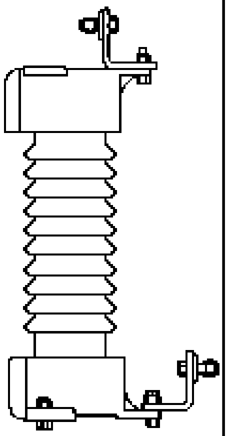

Medium Voltage Lightning Arrestors

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So What Is a Surge Arrester?

- Surge Arresters
  - "A protective device for limiting voltage on equipment…."
  - Insurance
  - CANNOT stop current but can only divert it
- MOV Arrester: An arrester containing Metal Oxide Varistor elements that limit the voltage during a surge
- Same concept as LV Surge Protection Devices

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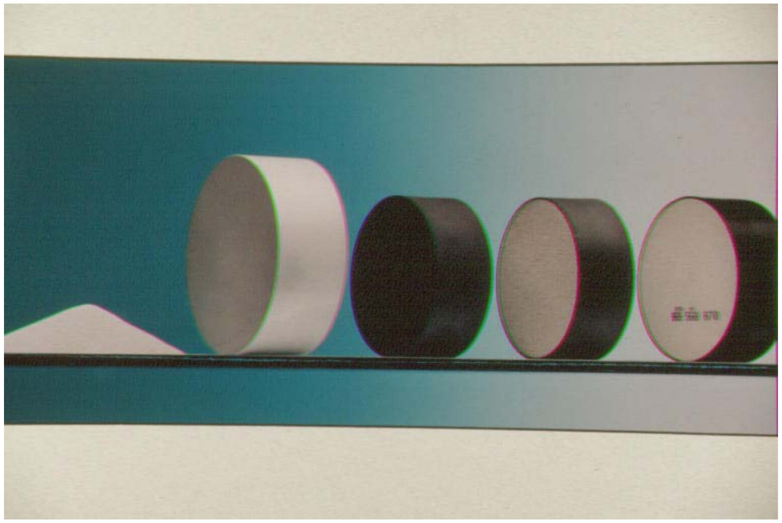
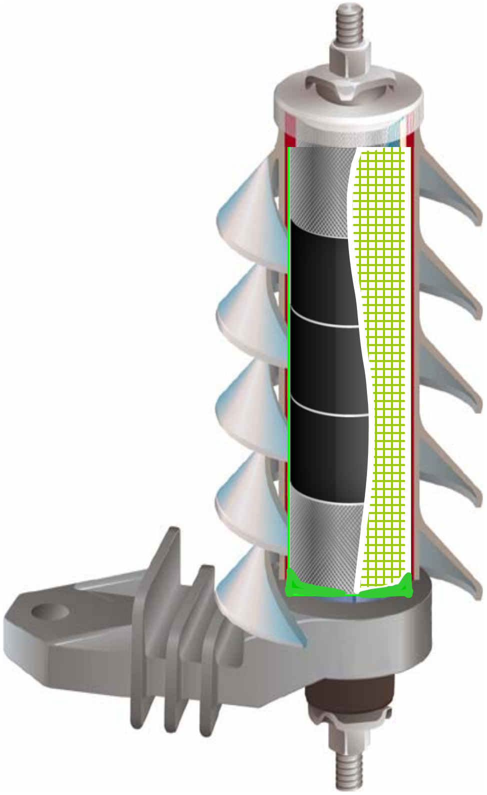
MOV Disk Design

- Material -- ZnO, bismuth, antimony, silver, Poly-vinyl-alcohol, …… 90% ZnO
- 40 Million grains/disk





MV Surge Protection Devices

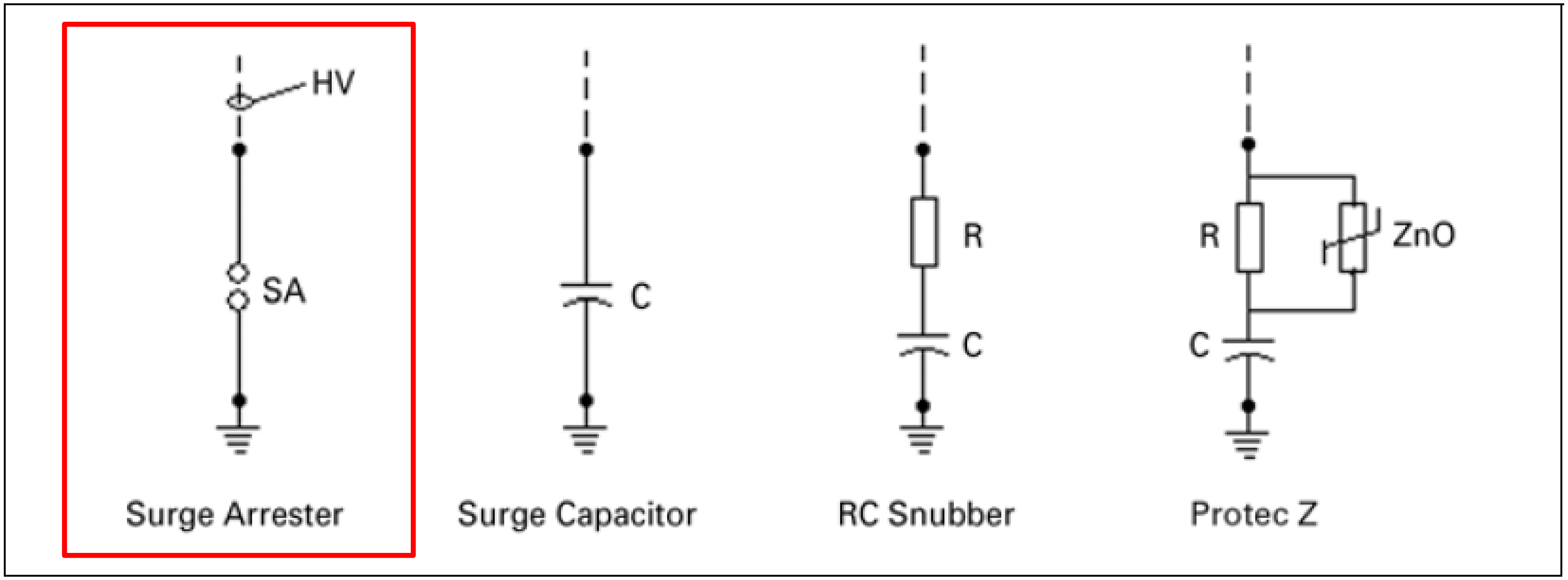


Figure 5.4-6. Surge Protection Devices

- Surge Arrestors – limit the magnitude of surge overvoltage.

MV Surge Protection Devices

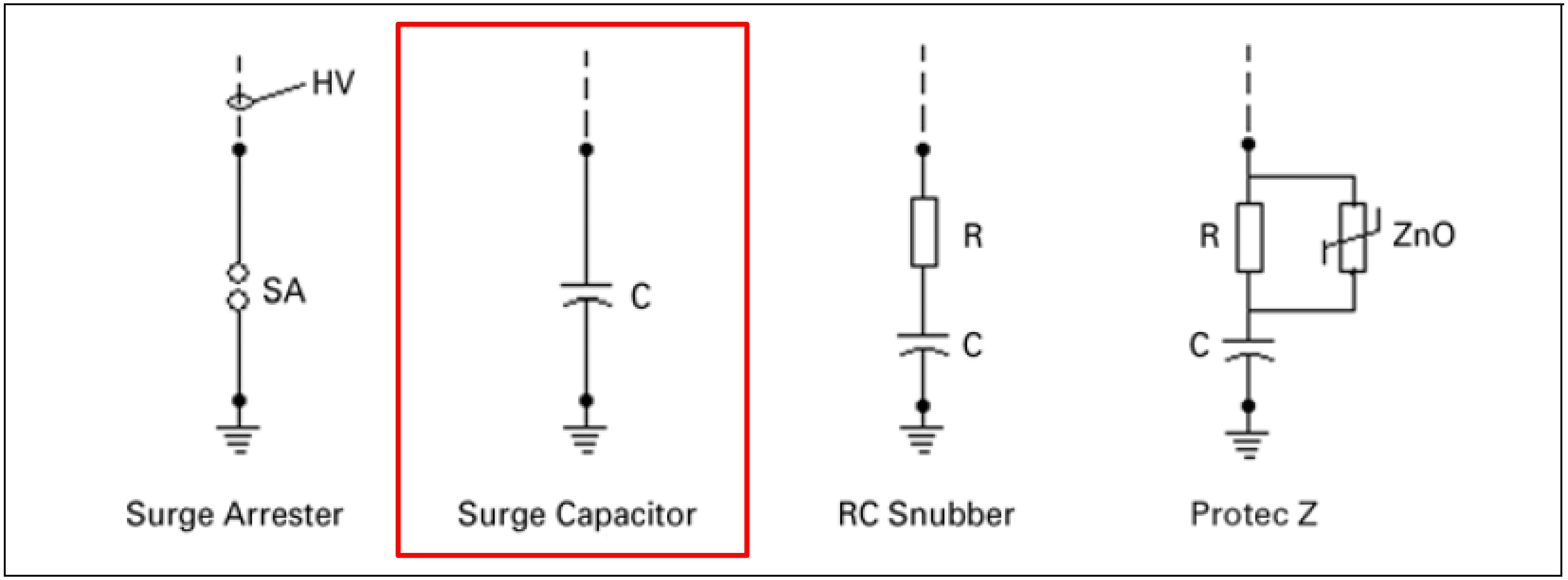


Figure 5.4-6. Surge Protection Devices

- Surge Capacitors – limit the rate of rise of surge overvoltage to protect turn-to-turn insulation of transformers and rotating equipment.

MV Surge Protection Devices

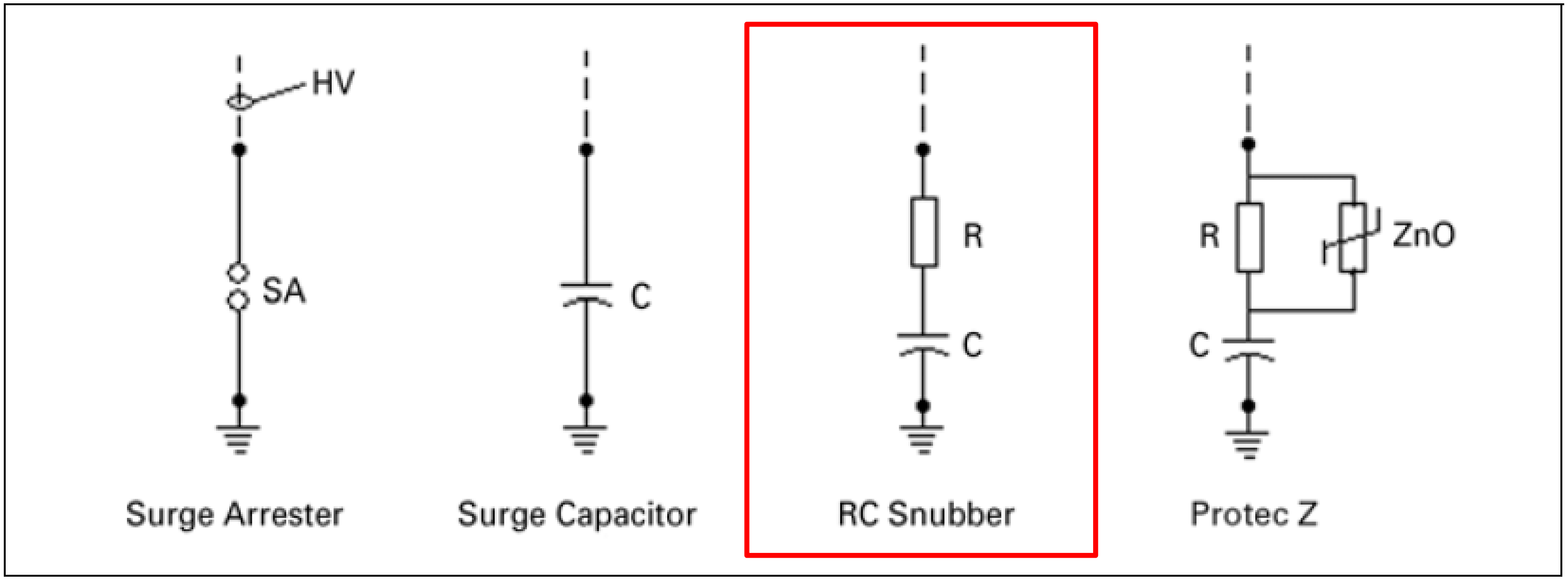


Figure 5.4-6. Surge Protection Devices

- RC Snubber – limits the reflection and magnitude of traveling waves of high frequency switching transients. R matched to surge impedance of the cables (≈20-30Ω). Capacitor has very low impedance to high frequency. $(Z_{cap} = \frac{1}{2\pi f})$

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MV Surge Protection Devices

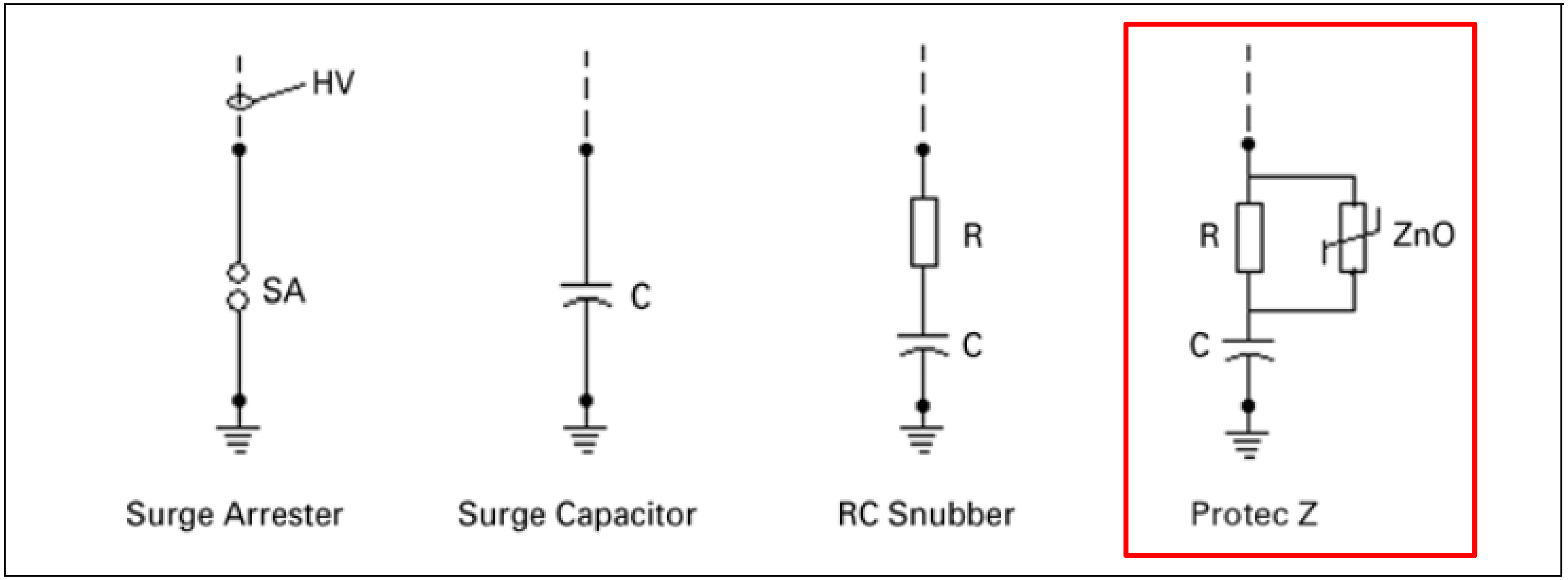

Figure 5.4-6. Surge Protection Devices

- Protect Z Snubber – adds a metal-oxide non-linear arrester to limit the peak amplitude of high frequency switching transients. (NOTE: For lightning protection, a standard surge arrestor is still required.)

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BIL

- Basic Insulation Level – Rating of the insulation level of a piece of equipment.
- Lightning arresters are coordinated with standard electrical equipment insulation levels (BIL) so that they will protect the insulation against lightning induced over voltages.
- This coordination is obtained by having an arrester that will discharge at a lower voltage level than the voltage required to break down the electrical equipment insulation.
- Surge capacitors can also be used to reduce the steepness of the wave fronts (dV/dT)

Types of Arresters

- Classes defined by:
  - Voltage rating
  - Protective characteristics
  - Pressure Relief
- https://www.nemaarresters.org/understanding-arresters/

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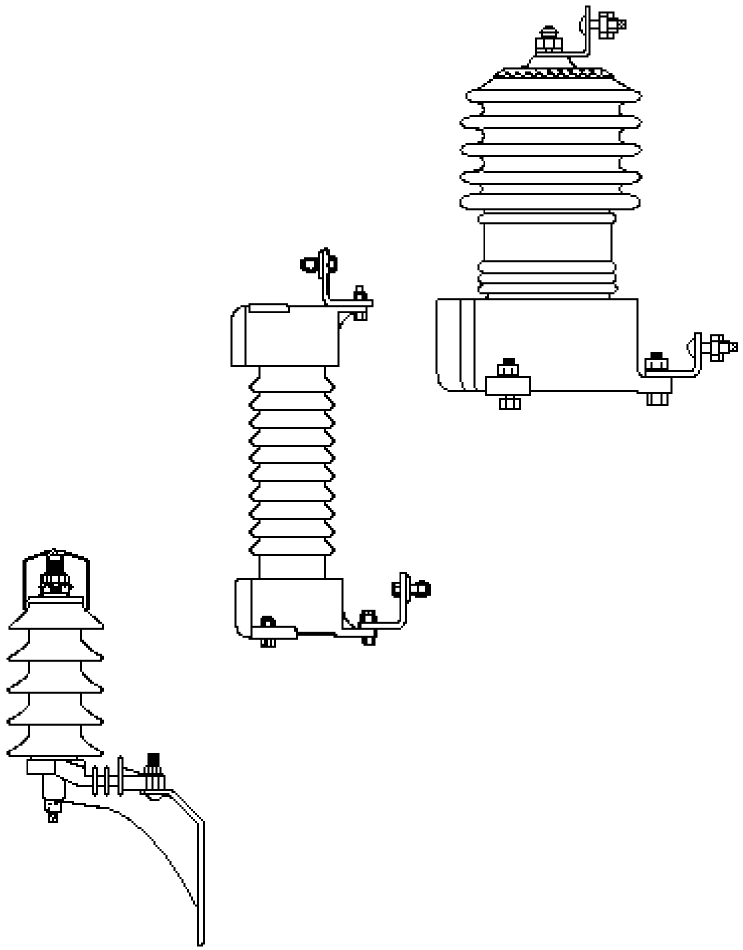
ANSI Arrester Classifications

- Station - 3 to 360kV
- Intermediate - 2 to 120kV
- Distribution - 1 to 36kV

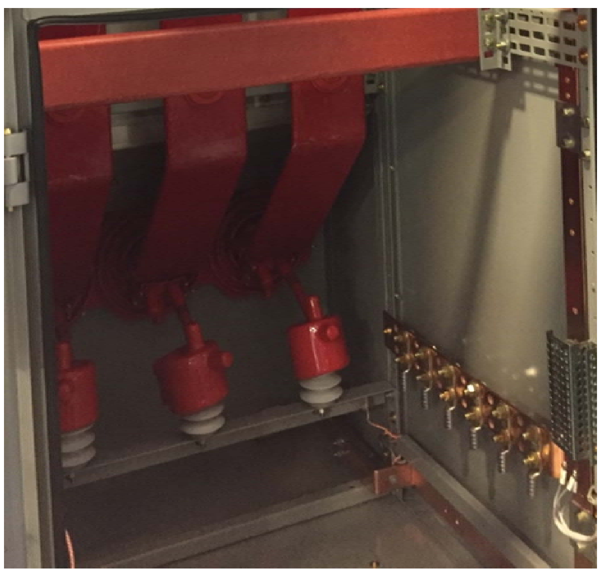


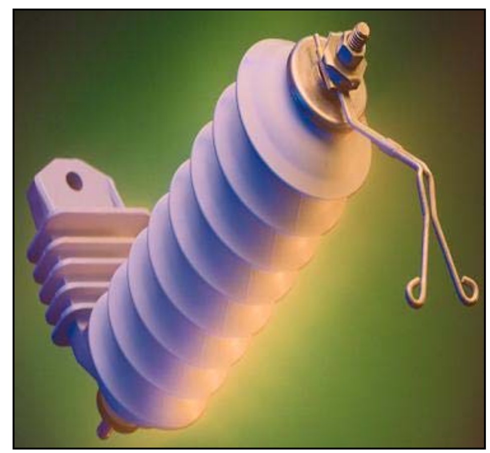
Station Class Arresters

- Station Class
  - Should be used where there are high fault currents and significant energy required to be absorbed due to switching surges
  - Offer the lowest discharge voltages of all arresters
  - Have pressure relief
  - Largest and most expensive class of arrester
  - Primarily used to protect large substations (>20MVA)
- Intermediate Class
  - Offer the second lowest discharge voltages available
  - Have pressure relief
  - Primarily used to protect medium to large substations (5 - 20MVA)

Distribution Class Arresters

- No pressure relief
- 1kV to 36kV ratings
- Applied on riser poles or in gear





Arrester Datasheet Characteristics

Protective Characteristics

Arrester Rating (kV)	MCOV (kV)	Minimum 60 Hz Sparkover (kV crest/$\sqrt{2}$)	Front-of-Wave Protective Level* (kV crest)	Maximum Discharge Voltage 8/20 µs Current Wave (kV crest)						Maximum 1.2/50 µs Sparkover (kV crest)
				0.5 kA	1.5 kA	3 kA	5 kA	10 kA	20 kA	
9	7.65	13.5	25.8/28.5	19.5	21.2	23.8	24.7	28.5	33.3	24.2
10	8.4	15.0	27.1/30.0	20.5	22.3	25.0	26.0	30.0	35.0	25.5
12	10.2	18.0	35.5/39.5	25.0	27.0	29.6	31.4	36.8	43.2	31.3
15	12.7	22.5	37.8/41.0	30.0	31.3	33.7	36.2	40.4	44.5	36.0
18	15.3	27.0	48.8/59.3	35.8	40.2	44.4	46.8	49.4	60.5	42.8
21	17.0	31.5	60.1/65.3	39.4	44.3	48.9	51.5	54.4	66.6	51.3
24	19.5	36.0	64.4/70.0	44.1	47.3	51.7	55.2	60.7	69.4	55.0
27	22.0	40.5	70.9/79.0	49.8	54.0	57.9	62.8	73.4	86.2	62.5

* First number is the value of the sparkover of the gap assembly based on a wave rising 100 kV per µs per 12 kV of arrester rating. Second number is based on 5 kA current impulse that results in a discharge voltage cresting in 0.5 µs.

- The maximum RMS voltage that can be applied between the terminals of the arrester before conducting
- MCOV is Approximately 84% of the Arrester Rated Voltage

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Arrester Datasheet Characteristics

Protective Characteristics

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				0.5 kA	1.5 kA	3 kA	5 kA	10 kA	20 kA	
9	7.65	13.5	25.8/28.5	19.5	21.2	23.8	24.7	28.5	33.3	24.2
10	8.4	15.0	27.1/30.0	20.5	22.3	25.0	26.0	30.0	35.0	25.5
12	10.2	18.0	35.5/39.5	25.0	27.0	29.6	31.4	36.8	43.2	31.3
15	12.7	22.5	37.8/41.0	30.0	31.3	33.7	36.2	40.4	44.5	36.0
18	15.3	27.0	48.8/59.3	35.8	40.2	44.4	46.8	49.4	60.5	42.8
21	17.0	31.5	60.1/65.3	39.4	44.3	48.9	51.5	54.4	66.6	51.3
24	19.5	36.0	64.4/70.0	44.1	47.3	51.7	55.2	60.7	69.4	55.0
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* First number is the value of the sparkover of the gap assembly based on a wave rising 100 kV per µs per 12 kV of arrester rating. Second number is based on 5 kA current impulse that results in a discharge voltage cresting in 0.5 µs.

- The voltage that appears across its terminals when impulsed at the given lightning current
- This is the most important characteristic!
- Should be compared with equipment BIL

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Arrester Datasheet Characteristics

Protective Characteristics

Arrester Rating (kV)	MCOV (kV)	Minimum 60 Hz Sparkover (kV crest/√2)	Front-of-Wave Protective Level* (kV crest)	Maximum Discharge Voltage 8/20 μs Current Wave (kV crest)						Maximum 1.2/50 μs Sparkover (kV crest)
				0.5 kA	1.5 kA	3 kA	5 kA	10 kA	20 kA	
9	7.65	13.5	25.8/28.5	19.5	21.2	23.8	24.7	28.5	33.3	24.2
10	8.4	15.0	27.1/30.0	20.5	22.3	25.0	26.0	30.0	35.0	25.5
12	10.2	18.0	35.5/39.5	25.0	27.0	29.6	31.4	36.8	43.2	31.3
15	12.7	22.5	37.8/41.0	30.0	31.3	33.7	36.2	40.4	44.5	36.0
18	15.3	27.0	48.8/59.3	35.8	40.2	44.4	46.8	49.4	60.5	42.8
21	17.0	31.5	60.1/65.3	39.4	44.3	48.9	51.5	54.4	66.6	51.3
24	19.5	36.0	64.4/70.0	44.1	47.3	51.7	55.2	60.7	69.4	55.0
27	22.0	40.5	70.9/79.0	49.8	54.0	57.9	62.8	73.4	86.2	62.5

* First number is the value of the sparkover of the gap assembly based on a wave rising 100 kV per μs per 12 kV of arrester rating. Second number is based on 5 kA current impulse that results in a discharge voltage cresting in 0.5 μs.

- This is the discharge voltage at faster rising impulses (1us rise time to 10kA)
- Characteristic of the second surge during a multistroke lightning event

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Arrester Datasheet Characteristics

Table 4. Discharge Voltages - Maximum Guaranteed Protective Characteristics for Type AZEH Surge Arresters.

Arrester Rating (kV rms)	Arrester MCOV (kV rms)	Front-of-Wave Protective Level (kV)*	Lightning Impulse Discharge Voltages (8/20 μ sec. kV)						Switching Impulse Discharge Voltages (kV)**		
		10 kA	1.5 kA	3 kA	5 kA	10 kA	20 kA	40 kA	500 A	1000 A	2000 A
3	2.55	9.4	7.2	7.6	7.8	8.3	9.3	11.0	6.5	6.8	–
6	5.10	18.4	14.4	15.0	15.4	16.3	18.1	21.2	13.0	13.5	–
9	7.65	27.5	21.6	22.5	23.0	24.3	26.9	31.4	19.5	20.3	–
10	8.40	30.2	23.7	24.7	25.3	26.7	29.4	34.4	21.4	22.3	–
12	10.2	36.6	28.8	30.0	30.6	32.4	35.6	41.6	26.0	27.0	–
15	12.7	45.4	35.8	37.3	38.1	40.2	44.3	51.6	32.4	33.96	–

- This is the discharge voltage at at slower rising surges. (30/90)
- Characteristic of the surges caused by device switching (breakers, reclosers, capacitors, etc.)

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Pressure Relief

- This is a measure of how much fault current can flow through the arrester after it is failed for what ever reason.
  - As an arrestor fails, a line to ground arc occurs which builds pressure inside the housing
  - The arrester acts like a short circuit and must be able to remain in tact while system fault current flows until an overcurrent device operates.

Table 1. UltraSIL (US, UH, and UX) Station-Class Ratings and Characteristics

Arrester Characteristic	Rating	
Arrester Voltage Ratings (kV)	3-240	
Cantilever Strength (in-lbs)	**Ultimate**	**MDCL-Static****
US (3-108 kV)	15,000	6,000
UH (3-108 kV) US (120-240 kV)	20,000	8,000
UX (3-108 kV) UH (120-240 kV)	35,000	14,000
Rated Discharge Energy (kJ/kV of MCOV)	**Single Impulse Rating**	
US (3-108 kV)	3.9	
UH (3-108 kV) US (120-240 kV)	6.2	
UX (3-108 kV) UH (120-240 kV)	10	
High Current Withstand* (kA)	100	
Impulse Classifying Current (kA)	10	
Pressure Relief Rating (kA rms sym.)	63	
System Frequency (Hz)	50/60	

* High current, short duration withstand (100 kA, 4/10 μs)

** Maximum design cantilever load–static or maximum working load is 40% of the ultimate.

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Pressure Relief Rating

- Distribution arresters are generally rated 20kA for 6 - 12 cycles
- Intermediate ≈ 40kA
- Station ≈ 63kA to 80kA

For a given application, the arrester selected should have a pressure relief/fault current capability greater than the maximum short-circuit current available at the intended arrester location.

Deadfront Underground Systems

Elbow Arresters

Deadfront Underground Systems

Parking Stand Arresters

Deadfront Underground Systems

Piggyback Arresters

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Wildlife Protection

- Can fit any standard arrester
- Retrofittable in the field
  - Added in the field while energized to avoid downtime
  - Can be installed with hotstick
- Discourages wildlife perching

Line terminal guard
Part number: AV698X1C

Ground terminal guard
Part number: AV731X1C

The line terminal and ground terminal wildlife protectors are shown here with the UltraSIL polymer housed Evolution™ surge arrester.

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Questions?